

Mill River River Corridor Management Plan Rutland County, Vermont



FINAL REPORT

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1.0 EXECUTIVE SUMMARY

The Mill River watershed extends from its headwaters in Mount Holly downstream through the surrounding landscape eventually entering the Otter Creek in Clarendon. The Mill River defines a significant valley shared by the towns of Mount Holly, Wallingford, Shrewsbury, and Clarendon and the many landowners that live along its banks. Historically a multitude of resources, at the cost of private landowners and state taxpayers, have been spent on protecting property adjacent to the river by methods such as channel straightening, dredging, berming, and streambank armoring. These practices are predictably temporary and often detrimental to the health of the river ecosystem as well as having negative flood and water quality impacts downstream all the way to Lake Champlain. In order to reduce the need for maintenance of traditional channel management applications along the Mill River and to shift the focus of management projects from short term control (2 year planning) to long term equilibrium and stability (50 to 100 year planning) the Rutland Natural Resource Conservation District (RNRCD) retained Round River Design (RRD) to complete a River Corridor Management Plan.

The Corridor Plan follows up on a Phase 1 and Phase 2 Stream Geomorphic Assessment conducted by the Rutland Regional Planning Commission (RRPC) and RRD respectively on the main stem of the Mill River Watershed during the autumn of 2007. Stream geomorphic assessments provide information about the physical condition of streams and examine the factors that influence their stability. The studies followed the assessment protocol (version 2007) developed by the Vermont River Management Program, Agency of Natural Resources (VTANR) as well as the "Vermont Agency of Natural Resources River Corridor Planning Guide to Identify and Develop River Corridor Protection and Restoration Projects" (developed by the VTANR in 2007). Because the geomorphic assessments studied the historic and current condition of the river, they are able to make predictions about how the Mill River will continue to adjust in the future. The results provided by the assessments were used to develop management strategies in this Plan.

This River Corridor Plan is meant to summarize information about the physical condition of the Mill River watershed; identify the factors that are influencing the stability of this system; and synthesize this information to identify restoration and management priorities. The Clarendon, Shrewsbury, Wallingford, and Mount Holly communities have the opportunity to provide long-term protection to the river corridor and encourage the reestablishment of functioning floodplain and healthy in-stream habitat through river corridor management, protection, and restoration.

Among the more significant findings of this plan:

- The majority of Mill River reaches are incised. The reduced floodplain access means increased stream energy is contained within the channel. Rather than providing storage during times of excess, these reaches now function to transport flow, sediment, and nutrients downstream (except for in areas where over-widening or channel constrictions (such as undersized bridges) reduce stream power sufficiently to cause deposition). In addition to the problems created by lack of sediment and nutrient storage, the lack of flood water storage means the Mill River is much more likely to see flood damage as a result of channel avulsions and catastrophic erosion rather than high water inundation. While floodplain ordinances (based primarily on flood inundation levels) may be incorporated in zoning regulations, fluvial erosion hazard mapping is recommended as a means to further reduce conflicts and protect valuable assets (see Appendix E).
- Channel incision and subsequent widening has been exacerbated by pervasive straightening, dredging, berming, armoring, and floodplain encroachment. Except for in



areas where intense community investment (such as in East Wallingford and Cuttingsville Village) may require active management, these activities have provided the false temporary appearance of stability while causing long-term significant detriment to the Mill River.

- Certain reaches of the Mill River are able to provide flow, sediment, and nutrient storage during flood events. Protecting these areas from channelization and floodplain development in order to perpetuate the functionality of these reaches would benefit the long-term health of the Mill River.
- Vegetation along streambanks provides an important long-term benefit to the river and landowners are encouraged to move ahead with revegetation efforts independent of other restoration efforts.
- Stormwater reduction is an important watershed-wide effort that should be considered with all new and existing development.
- The majority of Mill River reaches are classified as having high to extreme sensitivity indicating the possibility of rapid channel adjustment. The best approach to restoring these unpredictable reaches is through passive restoration efforts that focus on protecting the river corridor in order to reduce conflicts with land development. This approach would reduce costs for project implementation in comparison with approaches such as continued channelization or armoring, but will require time and patience on behalf of the community for stream channel processes to play out and for a more stable, ecologically healthy channel to develop.

2.0 PROJECT AND PROGRAM OVERVIEW

2.1 State of Vermont River Management Goals

The Vermont Agency of Natural Resources' (VTANR) goal is to, "manage toward, protect, and restore the equilibrium conditions of Vermont's rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner." The objectives of the Program include fluvial erosion hazard mitigation, sediment and nutrient load reduction, and aquatic and riparian habitat protection and restoration. The Program seeks to conduct river corridor planning, such as this Mill River project, in an effort to remediate the geomorphic instability that is largely responsible for flood damage and nutrient loading (to the Otter Creek and Lake Champlain), as well as loss of habitat and recreational opportunities. Additionally, the Vermont River Management Program has set out to provide funding and technical assistance to facilitate an understanding of river instability and the establishment of well-developed and appropriately-scaled strategies to protect and restore river equilibrium (Vermont River Management Program, personnel communication, 2006). Ultimately it is their strategy that sound research will lead to sound planning and meaningful and long-lasting restoration and management efforts.

The VTANR River Management Program uses the "river corridor" as a primary tool in its avoidance strategy to restore and protect the natural values of rivers and to minimize flood damage. River corridors consist of lands adjacent to and including the present channel of a river. The adjacent lands included in a "corridor" are those that are capable and perhaps likely to be occupied by the channel itself as the river meanders within a valley bottom over time (For a technical description of how they are delineated see "River Corridor Protection



Guide: Fluvial Geomorphic-Based Methodology to Reduce Flood Hazards and Protect Water Quality”: VTANR 2008). River corridor planning is conducted in Vermont to remediate the river instability that is largely responsible for excessive erosion and flooding, increased sediment and nutrient loading to surface waters, and a reduction in habitat (VTANR 2007a). Reducing current and future near-stream investment in infrastructure and achieving natural stream stability promotes a sustainable relationship between humans and rivers over time, minimizing the costs associated with floods (\$14 Million annually average in Vermont) and maximizing the benefits of clean water and healthy ecosystems (VTANR 2008).

2.2 Local Initiatives in the Mill River Watershed

Local restoration initiatives have been largely driven by the Rutland Natural Resource Conservation District (RNRCD) conservation interests, VTANR basin planning efforts, and the Rutland Regional Planning Commission (RRPC). The Upper Otter Creek Watershed Council (UOCWC), for example, is a project initiated by the RNRCD and VTANR. The group formed in May of 2003, after a series of public forums, at which many issues and concerns were identified. Since then, the UOCWC, the RNRCD, and/or RRPC have received funding to assess riparian buffers and geomorphic conditions along the Otter Creek and many of its significant tributaries including the Mill River (Rutland Regional Planning Commission 2005).

The Mill River Corridor Plan is derived predominately from data collected during a stream geomorphic assessment. Stream geomorphic assessments provide information about the physical condition of streams and the factors that influence their stability. The Vermont Agency of Natural Resources River Management Program has developed a series of protocols (Phase 1, Phase 2, and Phase 3) for the statewide assessment of rivers and streams. A Phase 1 Stream Geomorphic Assessment looks at broad scale landscape data, historical data, and limited field reconnaissance to begin to understand watershed characteristics and potential stressors. A Phase 1 Geomorphic Assessment of the Mill River was completed in 2007 by the Rutland Regional Planning Commission (RRPC). The Phase 1 project report summarized the results of this work (Rutland County Planning Commission, 2007). A Phase 2 Geomorphic Assessment of select reaches (predominately mainstem) of the Mill River was recommended by the RRPC to gather more detailed information about the stream channel and riparian corridor in order to inform current and future planning and restoration efforts. The RRPC retained Round River Design to perform a Phase 2 Stream Geomorphic Assessment of the main stem of the Mill River and a short segment of a tributary in the Towns of Clarendon, Shrewsbury, Wallingford, and Mount Holly during the autumn of 2007. In 2008, these same reaches were targeted for the development of this River Corridor Management Plan.

2.3 The River Corridor Planning Team

This River Corridor Plan has been developed following guidance provided by the VTANR document, “Vermont Agency of Natural Resources River Corridor Planning Guide to Identify and Develop River Corridor Protection and Restoration Projects” (VTANR 2007a) as well as guidance provided by VTANR watershed staff scientists. Funding has been provided by the Vermont Agency of Natural Resources. Support, review, and project development guidance were provided by Nanci McGuire (RNRCD – District Manager), Shannon Pytlik (VTANR – River Resource Scientist), and Ethan Swift (VTANR – Watershed Planner).



3.0 MILL RIVER STUDY AREA: BACKGROUND WATERSHED INFORMATION

3.1 Geographic Setting

3.1.1 Watershed Description

Located in Rutland County (with a very small portion in Windsor County), Vermont, the Mill River watershed area is 71.26 square miles (Figure 1). The Mill River drains from its forested headwaters in the Green Mountains southeast of Rutland predominately in the towns of Clarendon, Shrewsbury, Wallingford, and Mount Holly with very minor portions in Mendon, Killington, Mount Tabor, and Weston. The Mill River flows north westerly and joins the Otter Creek at approximately 550 feet above sea level in the town of Clarendon. The Otter Creek drains north into Lake Champlain carrying with it the waters, sediments, and nutrients of the Mill River. The combined length of the Mill River reaches targeted through this River Corridor Plan is approximately 15 miles (Figure 2).

3.1.2 Political Jurisdictions

The Mill River mainstem reaches are located in Rutland County in the Towns of Clarendon, Shrewsbury, Wallingford, and Mount Holly. All towns are members of the Rutland Regional Planning Commission. The State of Vermont Water Resources Board classifies and regulates the use of all public waters. The Vermont Agency of Natural Resources issues permits regarding water and stream use. The U.S. Army Corps of Engineers also issues permits and enforces water law in the state.

3.1.3 Land Use History

The Mill River, like many waterways, has been vitally important to the inhabitants of this land. Before the colonists arrived in Vermont, rivers, streams, and lakes were a major avenue of transportation for the Algonquin and Iroquois people. Colonial settlements were established in Vermont in the late 1700's on the back of forestry and agriculture. Settlements typically arose around gristmills and sawmills at suitable sites along rivers and streams. At least a dozen mills dotted the Mill River during the 18th & 19th century. The mills used water from the river and its tributaries to power saws, grists, and fulling and carding machines for preparing wool. The exact location of many of these old mills is difficult to discern in the field as many years have passed. Several known mill locations include the Kingsley's Grist Mill, which served some of Vermont's grain production needs from 1882 until 1935 which was located at reach M03-B near the Shrewsbury and Clarendon town line. Also on the Mill River near the same town line was Smith's Sawmill which operated well into the 1820's. In Cuttingsville, several mills were in harnessing energy from the river from 1820 until 1927 when the great flood washed out the low (~5 foot high) dam spanning the river (at the bedrock grade control on reach M06 upstream from the Route 103 bridge). According to Klyza (1999), mill sizes were typically kept small in order to accommodate the needs of farmers upstream and downstream of the dams. Upstream farmers wanted to ensure that their croplands would not be severely inundated and downstream farmers demanded that they receive enough water yearlong.

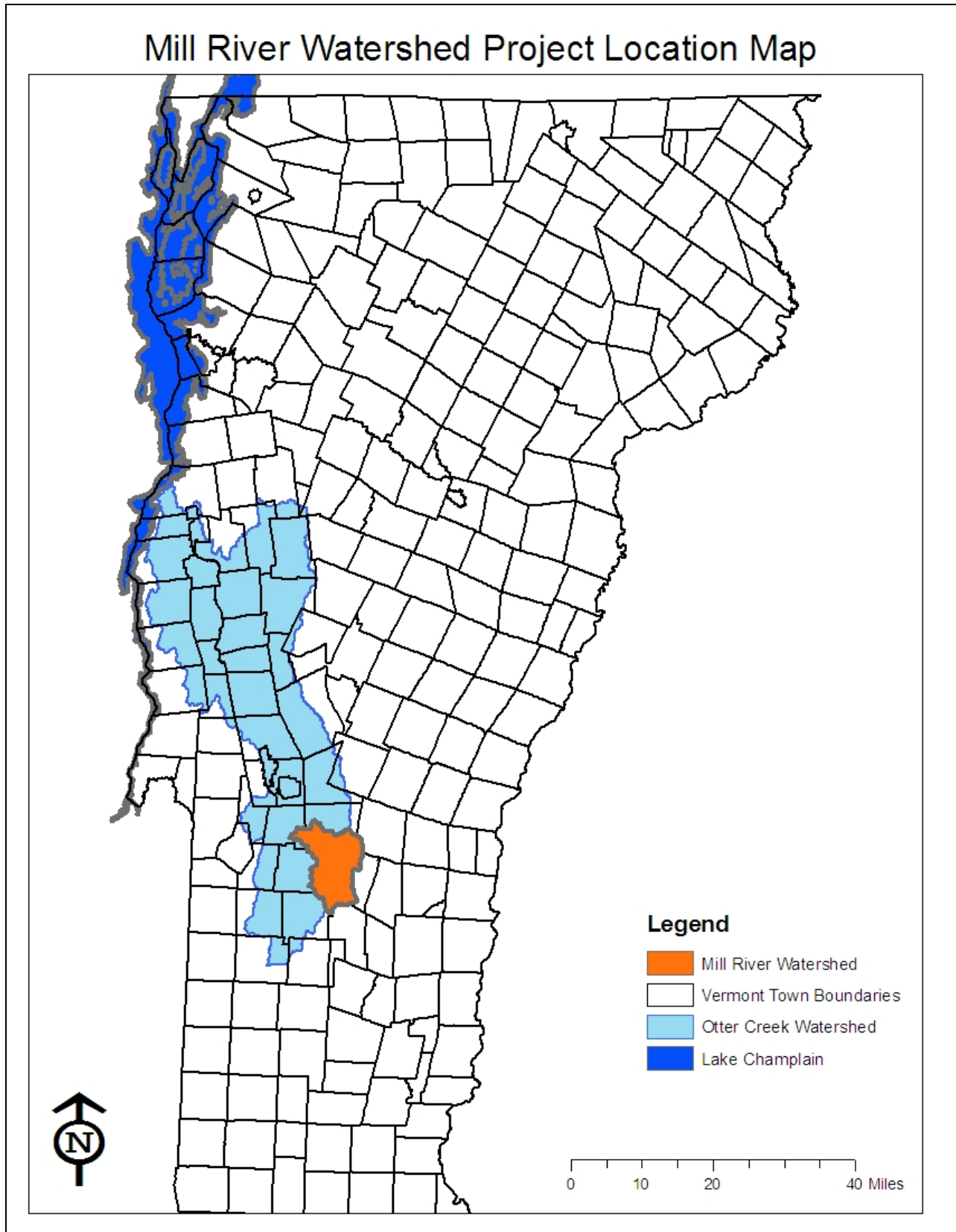


Figure 1: Project Location Map

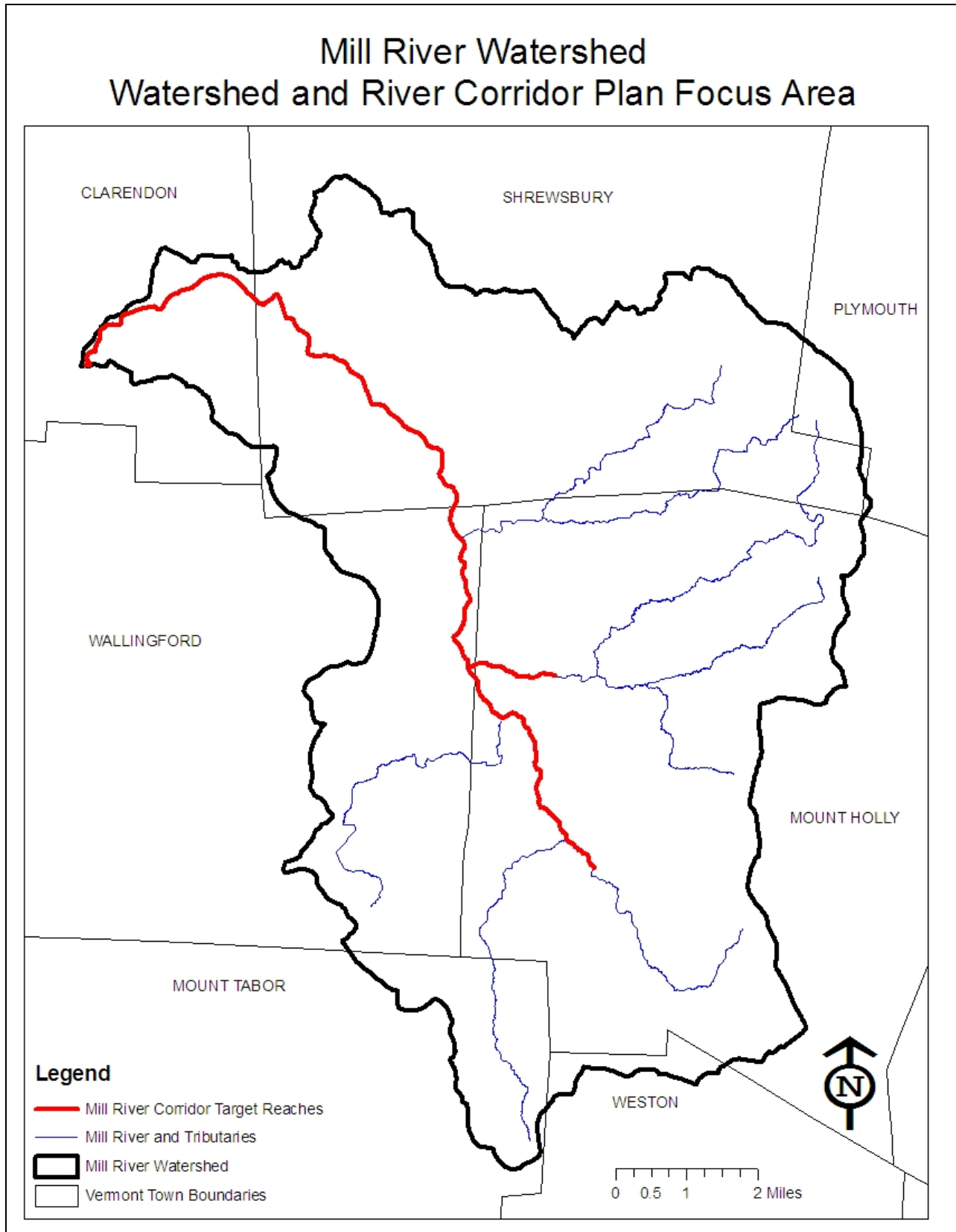


Figure 2: Target Area for the Mill River Corridor Plan.



Agriculture tended to be largely subsistence farming during the early years of settlement and then shifted to primarily growing wheat as a cash crop as demand from non-farming populations (especially southern New England) increased and transportation costs decreased. Competition with mid-western farmers, nutrient-depleted soils, demand from the growing textile mills of southern New England, and a greater need for cash income, among other reasons, caused a shift to sheep farming in the 1820's. Sheep farming enabled Vermonters to put to use the vast areas of deforested land and it became so widespread that, in 1840, during its peak, sheep out-numbered humans 6 to 1 statewide (Klyza, 1999). In the mid- to late- eighteen hundreds, falling wool prices and the availability of horse drawn mechanical farm equipment enabled farmers to develop larger tracts of land to grow feed for dairy cows and another shift in agriculture ensued (Albers, 1999).

While mills were at work utilizing the water within the river, transportation routes were being established in the valley carved by the Mill River and its tributaries. Upon completion of the Bellows Falls to Rutland railroad in 1849, East Wallingford grew up around a station on that line as a lumbering and manufacturing center (Wallingford Town Plan, 2004). The construction of the railway had enormous impacts on the riparian corridors that it passed through as rivers were straightened to facilitate its passage.

The great flood of 1927 led to major changes in land use in the Mill River Watershed and throughout the state. The flood caused massive damage to the state's railroad infrastructure (as well as bridges, homes, farms and businesses) and although much was rebuilt, the growing affordability and popularity of the automobile spurred the construction of improved roads. Commercial and residential development expanded along these transportation corridors (again, following the rivers for the most part) and the percentage of impervious surfaces in the river corridor enlarged. Roads also increased tourism, and with the construction of the highway systems in the 1960's the number of ski resorts and second homes rose sharply. The Civilian Conservation Corps also launched a huge flood control initiative following the 1927 disaster that included erosion prevention, reforestation, habitat protection, reclamation of abandoned farmlands, and the construction of recreational trail networks (the extent of these efforts on the Mill River was not determined).

Today the Mill River is dominated by forested hill tops with residential, commercial, and agricultural lands concentrated near the river valley bottom and along select tributaries (Figure 3).

3.2 Geologic Setting

Streams are transport systems that carry *water* AND *sediment* from highlands to lowlands. The geology of a watershed determines: the source material that water will transport; the conditions that cause the material to be carried; the rate of channel adjustments in response to the energy of flowing water; and also influences the chemistry and ecology of stream systems.

3.2.1 Mountain Building and Bedrock Geology

In a broad geological context the Mill River spans two larger physioregions. The "Vermont Valley" – a continuation of the Champlain Valley that lies to the west of the Green Mountains and north of the Taconic Mountains where hills thrust up from bedrock dominate the lower river. The upper reaches of the Mill River are considered part of the "Green Mountain"



Mill River Watershed Land Use and Land Cover (Present)

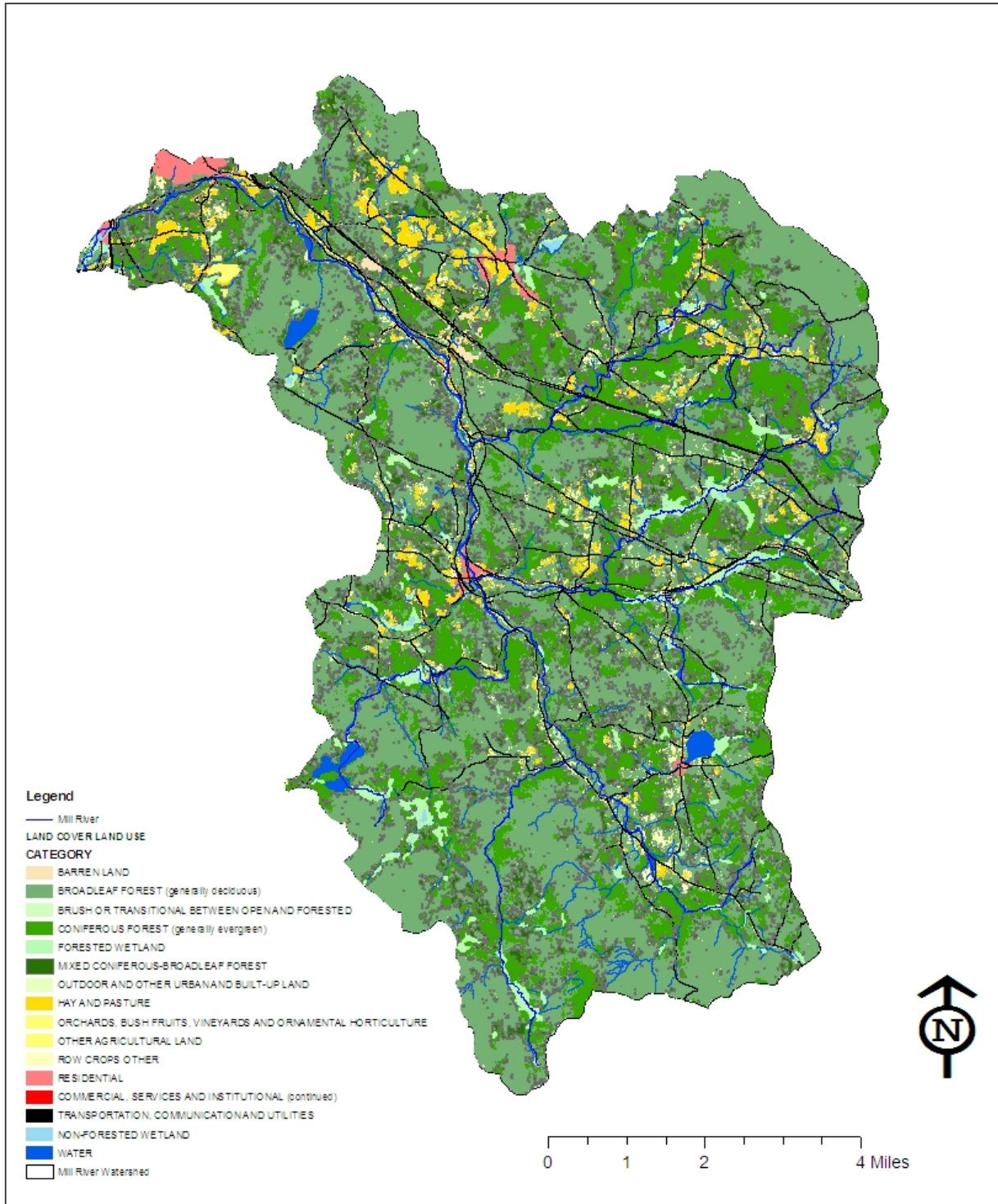


Figure 3: Present day land use and land cover of the Mill River Watershed.



physioregion a huge anticlinorium comprised of three anticlines that have been compressed and uplifted and trend in a north-south direction (Stewart 1972).

The upper reaches of the Mill River flow over bedrock of the Green Mountain Physioregion. According to Stewart (1972), Precambrian basement rock (Mount Holly Complex) forms the core of the Green Mountains and the bedrock geology of the upper Mill River watershed. These rocks were created about 1,200 million years ago during the Grenville Orogeny. During this period, lasting approximately 80 million years, the proto-North American plate collided with another continent approaching from the east, creating a massive mountain chain which was later completely eroded away (Klyza, 1999). As a result of the mountain building events, the Mount Holly Complex is the most highly metamorphosed rock of the whole region. The rock is a complex mixture of schists and gneisses with large areas of quartzite and small concentrations of calcite and dolomite marble.

As the Mill River descends out of the Green Mountains it enters the Vermont Valley physioregion; a series of mostly Cambrian carbonate rock composed both of dolomitic and limestone marbles with occasional quartzite members. As indicated on a map titled, "Areal Geology of the Rutland Area" (Vermont Geological Survey 1952), the Mendon Formation (a Lower Cambrian quartzite formation) is found near reach M04. The Danby Quartzite formation (Upper Cambrian) forms the beginning of the Lower Clarendon Gorge with Winooski Dolomite and Monkton Quartzite forming the lower gorge. From here the Mill River spills out to the valley floor of the Otter Creek and into an area dominated by glacial drift and surficial deposits.

In the areas where bedrock does directly underlie the river channel; the stability of a river channel is typically improved. Exposed bedrock along the stream bottom and/or channel walls typically prevents rapid incision and planform adjustments. In the Mill River, channel spanning bedrock is found in reaches M11-B, M06, M04, M03-C, M03-B and M02. This bedrock provides a more stable stream channel in these reaches and in most cases has limited incision directly upstream and downstream as well. These channel spanning bedrock formations are known as "grade controls" since they set the grade (i.e. the slope) of the river to a certain set elevation.

3.2.2 Glacial History and Surficial Geology

According to Wright and Larsen (2004) almost all of the surficial materials [in Vermont] owe their origin, either directly or indirectly, to the Laurentide ice sheet. The Laurentide ice sheet was the last big continental-scale glacier that covered all of New England. It first formed in the Hudson's Bay region of Canada sometime between 80–100,000 years ago. As the climate slowly cooled the ice sheet grew and advanced slowly towards New England, flowing south and east, up the Mill River valley. As the ice sheet advanced and thickened it eventually overwhelmed and completely buried the Green Mountains (as well as the Adirondacks and White Mountains) and, by approximately 23,000 years ago, extended as far south as Long Island. As the climate rapidly warmed the ice sheet responded by thinning and retreating to the north leaving most of Vermont ice-free by approximately 14,000 years ago, but having a very significant impact on the surficial geology of the landscape.



The surficial materials in the Mill River region are composed of sediments transported by glaciers or by melt water from streams or deposits made in small lakes associated with glaciation. The exception is the recent alluvium from postglacial floodwaters that forms a thin veneer on land adjacent the river (i.e. floodplain). Till (unsorted glacial debris deposited directly from melting ice) contains a wide variety of particles sizes. According to Stewart (1972), till covers the uplands of the Rutland region as a thin veneer generally less than 10 feet thick and much thicker in the valleys. At the base of the Green Mountains, near the Vermont Valley, kame terraces, kames, and valley train deposits (outwash from glacial streams) can be found.

The Phase 1 Stream Geomorphic Assessment (Rutland Regional Planning Commission 2007) used soil maps (provided by the Natural Resource Conservation Service) to determine that ice-contact, glacial till, and alluvial deposits are the dominant surficial geologic materials in the Mill River watershed. Alluvium soils are frequently flooded and have high erodibility potential. Ice contact soils are infrequently flooded; however have high to severe erodibility. Glacial till deposits are infrequently flooded and have high erodibility.

3.3 Geomorphic Setting

3.3.1 Description and Mapped Location of Study Reaches

The Phase 1 Assessment of the Mill River Watershed (Rutland Regional Planning Commission, 2007) delineated geomorphic reaches (sections of river that are expected to exhibit similar characteristics). Reaches were defined according to VTANR Phase 1 protocol based on variations in valley confinement, slope, sinuosity, and soils. Based on the channel and watershed stressors identified during the Phase 1 Assessment, fifteen mainstem reaches and one tributary reach of the Mill River were prioritized for Phase 2 Stream Geomorphic Assessments in 2007. These targeted reaches were expected to demonstrate higher degrees of channel adjustment and sensitivity. As depicted in Figure 5, several of these fifteen reaches were further subdivided into “segments” due to localized variations in stream type, channel and floodplain encroachment, incision, and/or other significant differences observed during the Phase 2 field assessment. In total 22 unique sections of river were investigated for the Phase 2 assessment.

3.3.2 Longitudinal Profile, Alluvial Fans, and Natural Grade Controls

The Mill River drops at an average slope of 1.4% from reach M15 to the confluence with the Otter Creek (a valley distance of almost 13 miles) (Figure 4). Soil profiles at significant slope changes located at reaches M11-B and M01 indicate the possible presence of alluvial fans. Natural bedrock grade controls (where bedrock spans the river channel and prevents rapid incision) were located at reaches M02, M03, M04, M06, and M11.

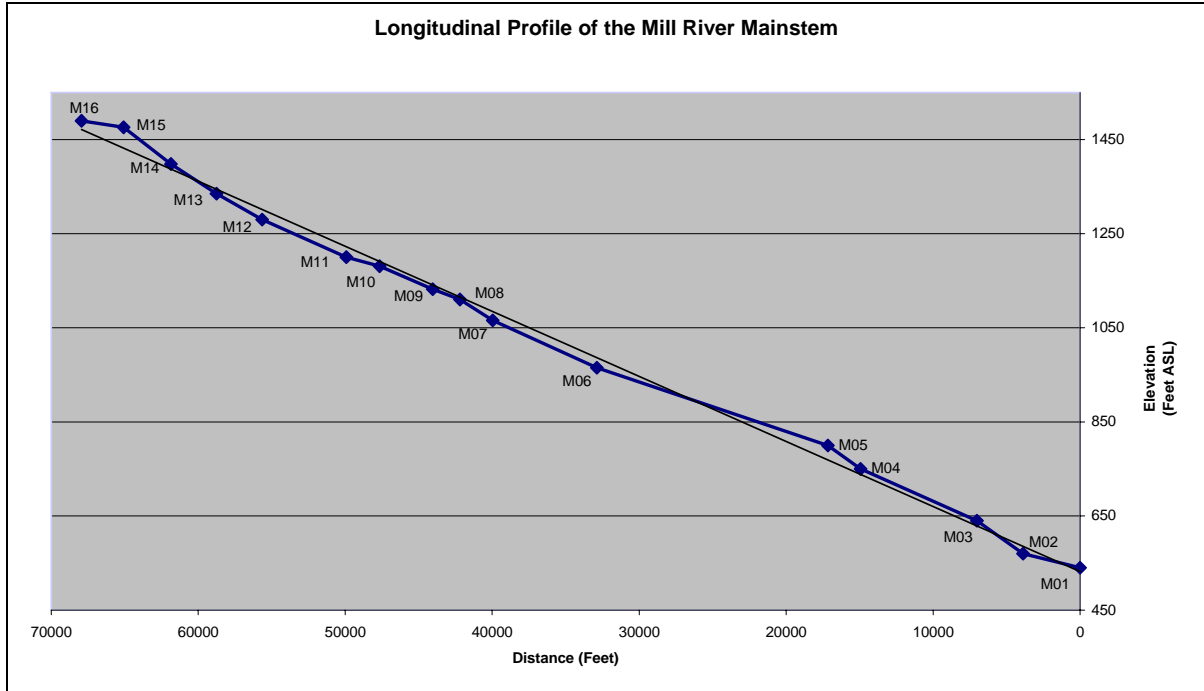


Figure 4: Longitudinal Profile of the Mill River.

3.3.3 Valley and Reference Stream Types

Reference stream and valley types are designated to describe stream channel forms and processes that would exist in the absence of human-related changes to the channel, floodplain, and/or watershed. Reference stream types are based largely on characteristics of the valley, geology, and climate and are identified using data from both the Phase 1 and Phase 2 Assessments (VTANR 2007b). Reference stream types are based in the science of fluvial geomorphology which informs us that given consistent inputs (average annual precipitation and sediment input), every river has a single most probable form toward which it is constantly working (Leopold 1994). Given the long history of stream channelization and human-related changes to the Vermont landscape it is common to observe that existing stream and valley conditions are significantly different than what one would expect to find in a pristine watershed. Recognizing differences between current on-the-ground conditions and a streams “most probable form” may be useful for determining restoration and management approaches (as outlined in section 5.0).

Table 1 describes the reference stream and valley types for the Mill River study reaches. The majority of the mainstem of the Mill River is by reference a “C” type channel dominated by gravel substrates, an unconfined floodplain, and a riffle-pool bedform (see Rosgen 1996 for stream type definitions). Several of the mainstem reaches are reference “B” type channels that have steeper slopes, a naturally confined floodplain, and in this case, dominated by bedrock on the stream channel bottom.

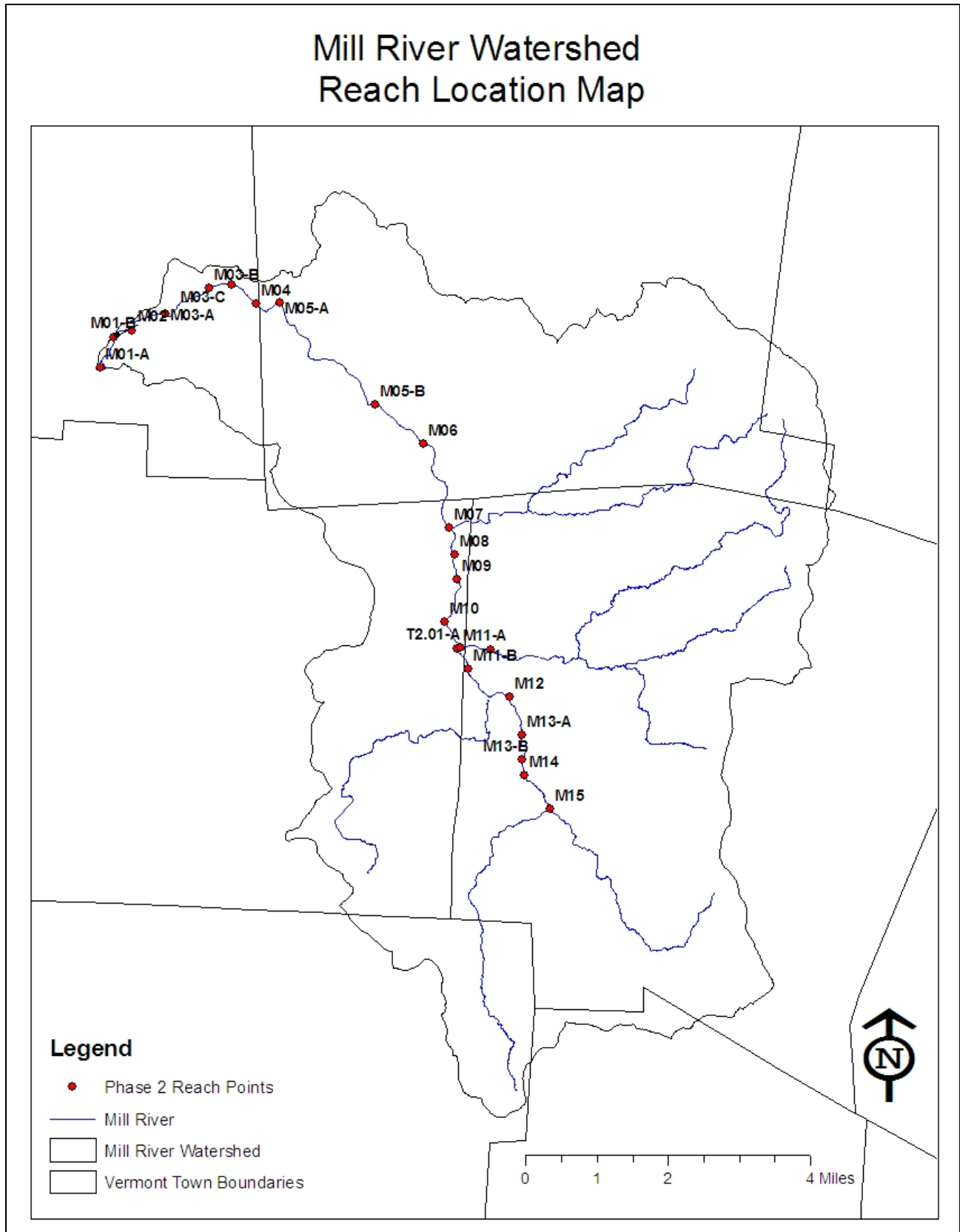


Figure 5: Reach location map for the Mill River Phase 2 Stream Geomorphic Assessment



Table 1: Reference Valley and Stream Types for the Mill River						
Segment Number	Valley Type	Expected Channel Width (ft.)	Channel Slope (%)	Sinuosity	Reference Stream Type	Reference Bedform
M15	Very Broad	35.9	0.45	1.08	C4	Riffle-Pool
M14	Very Broad	45.4	2.29	1.06	C3b	Riffle-Pool
M13-B	Broad	45.9	1.85	1.10	B3	Riffle-Pool
M13-A	Broad	45.9	1.85	1.10	C4	Riffle-Pool
M12	Very Broad	46.5	1.74	1.02	C4	Riffle-Pool
M11-B	Very Broad	55.1	1.29	1.09	C4	Riffle-Pool
M11-A	Very Broad	55.1	1.29	1.09	C4	Riffle-Pool
M10	Broad	66.4	0.80	1.04	C4	Riffle-Pool
M09	Narrow	67.5	1.36	1.00	C4	Riffle-Pool
M08	Narrow	67.9	1.16	1.03	C3	Plane Bed
M07	Broad	75.8	1.85	1.06	C4	Riffle-Pool
M06	Broad	77.2	1.33	1.07	C4	Riffle-Pool
M05-B	Broad	83.6	0.99	1.06	C4	Riffle-Pool
M05-A	Broad	83.6	0.99	1.06	C4	Riffle-Pool
M04	Confined	83.7	2.25	1.00	B1	Bedrock Gorge
M03-C	Semi-Confined	84.5	1.33	1.04	B4	Plane Bed
M03-B	Confined	84.5	1.33	1.04	B1	Bedrock Gorge
M03-A	Broad	84.5	1.33	1.04	C3	Riffle-Pool
M02	Confined	84.7	2.22	1.01	B1	Bedrock Gorge
M01-B	Very Broad	85.6	0.62	1.25	C4	Riffle-Pool
M01-A	Very Broad	85.6	0.62	1.25	C4	Riffle-Pool
T2.01-B	Very Broad	41.1	1.46	1.07	C4	Riffle-Pool
T2.01-A	Very Broad	41.1	1.46	1.07	C4	Riffle-Pool

3.4 Hydrology

As reported in the Phase 1 Assessment Report (Rutland Regional Planning Commission 2007), most of the Mill River watershed is currently forested. Some subwatersheds were reported to have as much as 9% in urban land use and 6% in cropland/pasture based on an analysis of data obtained from the Vermont Center for Geographic Information. Within the stream corridor urban land use development rose to as much as 60% of the corridor of one reach (M10).



These numbers are important because development in the watershed, both current and historic, may have a large impact on fluvial erosion, water quality, and habitat quality. For instance, according to a study conducted at the University of Maryland (Barnes et al, 2007), declines in biological integrity and habitat quality are observable in watersheds with impervious cover as low as 10%. The alteration of first-order, and in some cases, second-order channels (the small feeder streams that join to become the major tributaries to the Mill River) is problematic since runoff and sediments formerly distributed among many small channels become concentrated to fewer channels. The outcomes of this are more rapid flow velocities and flood peaks downstream leading to erosion and enlargement of stream channels; the washing-out of culverts and crossing structures not previously sized to handle such flows; as well as other detrimental affects.

Channel and bank instability, which leads to the physical degradation of streams, is aggravated by the increased flooding and increased flow concentration that follows increased imperviousness as a result of poor development. The signs of instability, however, may not become evident for several years following development. Signs of instability include channel widening by bank erosion or a deepening of the channel through down-cutting. With the former, channel beds may become covered in sediment; with the latter, beds are subject to frequent scours.

The Maryland study continues to describe that, “When development occurs on floodplains not previously developed, natural flooding will inevitably threaten the people and property inhabiting those floodplains. What’s more, areas that did not commonly flood before urbanization may suffer more frequent inundations due to the greater volumes of runoff and increased flood heights associated with imperviousness. Properties and structures may be threatened by bank erosion from streams’ whose channels have been destabilized by upstream development (Barnes et al, 2001).”

In the context of the Mill River the conditions for this instability exist and the human reaction to instability such as channel dredging, berming, stoning, ditching of small runoff channels, and straightening appears to be a pattern that is widespread and persistent.

3.4.1 Stream Gage Information and Flood History

According to the Vermont Agency of Natural Resources document “Municipal Guide to Fluvial Erosion Hazard Mitigation” (2006), “Of all the natural hazards experienced in Vermont, flooding is the most frequent, damaging, and costly.” The guide documents that over the last 50 years, flood recovery has cost the state an average of \$14 million a year and that during the period of 1995-1998 alone, flood losses in Vermont totaled almost \$57 million. Of particular concern for towns and properties near streams, it notes that, “While some flood losses are caused by inundation (i.e. waters rise, fill, and damage low-lying structures), most flood losses in Vermont are caused by “fluvial erosion”. Fluvial erosion is erosion caused by moving water and can range from gradual streambank erosion to catastrophic changes in river channel location and dimension during flood events (Figure 6).”



Figure 6: These images show damage from the 1927 flood. Left image is looking towards the intersection of Route 140 and Route 155 (Reach M10) in East Wallingford. Right image is of route 103 washout in Cuttingsville near reach M06/M07.

The Municipal Guide further documents that, “Closer study of our rivers and streams reveals that Vermont’s erosion hazard problems are largely due to pervasive, human-caused alteration during the past 150 to 200 years of our waterways and landscapes they drain. By the end of the 19th century, forests had been cleared from many watersheds, resulting in major changes in watershed hydrology and sediment production. Towns and villages, the centers of commerce, grew on the banks of rivers, whose role in power generation and transportation at first outweighed flood risks. In addition, many watersheds were changed by development, agriculture, log drives, roads and railways.” The legacy of this landscape manipulation is rivers and streams, such as the Mill River, which are unstable and prone to sudden and significant fluvial erosion (Vermont Agency of Natural Resources 2006).

To further concern streamside landowners, precipitation trend analysis suggests that intense, localized storms, which can cause flash flooding, are occurring with greater frequency (Vermont Department of Public Safety, 2006). In order to better understand the flood history of the Mill River, long term data from the U.S. Department of the Interior, U.S. Geological Survey (USGS) gauge on the Otter Creek in Rutland, VT (Figure 7) and data from a smaller nearby stream, the Ottauquechee River near West Bridgewater, VT (Figure 8), were obtained (United States Geological Survey 2007). Seventy-eight years of record are available for the Otter Creek gauge at Rutland, VT which provides a continuous record of flow from 1929 through the present. Only the last twenty-two (1985-2007) years of records are available on the Ottauquechee River.

The Otter Creek generally has good access to its floodplain and floods at least once each year at spring runoff. The long term record at the Otter Creek gauge shows a 25 year flow was recorded in 1973 and 10 year flows have been recorded in 1947, 1949, 1976, 1977 and 1987. In 1938, during the New England Hurricane, the Otter Creek reached a peak of 13,700 cfs, the only flow greater than the 50 year flood stage measured on this gauge (which was not operational during Vermont’s largest flood, 1927) (Vermont Agency of Natural Resources, 2007b). In the near term record of the Ottauquechee River gauge (from 1985 to 2006) major events occurred in 1996, 1998, 2000, and 2002.

It is safe to presume that future flooding and flood damage are a certainty. Preparation for and response to flood situations may have significant and long-lasting influence on whether flooding continues to be a cause of significant financial harm or whether it becomes a natural phenomenon that is ultimately a long-term expression of river stability and dynamism. It may possibly even become something to be appreciated for, under the right conditions, flooding



can replenish nutrients in agricultural fields and, where wetlands are adjacent to streams, create temporary habitat for the reproduction of many aquatic and riparian species.

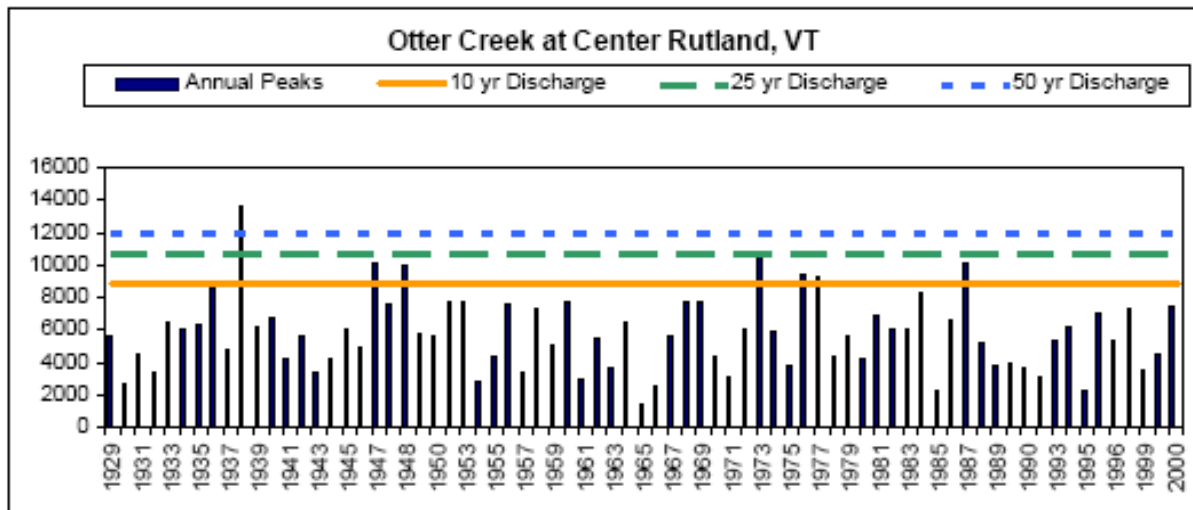


Figure 7: Flood frequency analysis for Otter Creek, Rutland, VT.

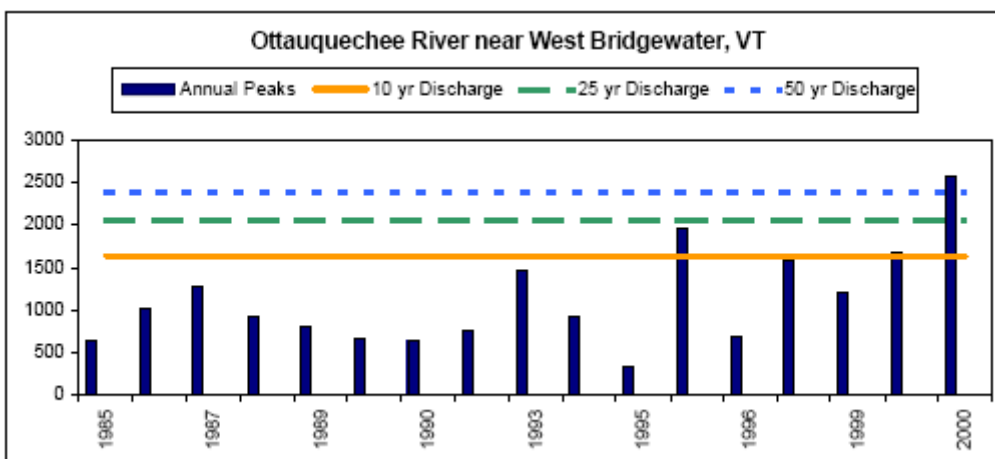


Figure 8: Flood frequency analysis for Ottauquechee River at West Bridgewater, VT.

3.5 Ecological Setting

3.5.1 Distribution of In-stream, Riparian, and Wetland Habitats

During the Phase 2 Assessment a rapid habitat evaluation was conducted for twenty assessed segments. The habitat observations found that in-stream shelter within many of the upstream reaches consisted only of small pocket pools behind large boulders. In-stream habitat has suffered due to channel straightening and dredging which have reduced the quality and depth of pools and where large woody debris (such as logs and tree stumps) has been removed from the channel. Additionally, fine sediments from bank erosion and surface water



runoff from roads and other clearings have caused some loss of habitat as cobbles and gravels on the stream bottom become filled in.

Shading from the riparian corridor varied between very good to poor with much of the stream lacking adequate buffer or simply being over-wide (high width/depth ratio) and therefore being susceptible to thermal pollution (see Figure 9). Many reaches, especially near the villages had major intrusion into their river corridor from roads and many had inadequate riparian buffers due to historic and /or recent land clearing. In addition, where roads and railroads border the stream, vegetation tends to be disturbed and not as robust as if the stream were meeting an unaltered floodplain. The benefits of wider riparian corridors are numerous. From a wildlife perspective, riparian buffers offer corridors for habitat and migration, while large woody debris provides habitat pools for aquatic life (Magillan et al., 2008). From a geomorphic perspective, forested riparian buffers improve bank stability and help control erosion (McBride et al., 2008). Also, large woody debris in streams helps maintain natural flow by providing high flow mitigation and acting as sediment traps. Finally, from a water quality perspective, riparian buffers help control nutrient cycles and shading helps control water temperatures needed to sustain healthy ecosystems.

Overall, the habitat assessment results were similar to the geomorphic assessment results (indicating major declines in stream stability) implying that the ecological health of the Mill River is closely related to the geomorphic condition of the stream.



Figure 9: Despite a well forested riparian buffer, over-wide reaches such as M03-A may suffer from thermal pollution due to lack of shading.

3.5.2 Unique Plant and Animal Communities

The VTANR Biomonitoring Section monitors the Mill River on a regular basis. None of the species that have been collected from the Mill River watershed are considered unique or rare in Vermont. The Vermont Fish and Wildlife Department, Nongame and Natural Heritage Program's GIS data layer "Rare, Threatened and Endangered Species & Significant



Communities” does, however, indicate the presence of noteworthy biota in the Mill River watershed, particularly in some of the tributaries (the information describes several plants, a mammal, and a bird that are known to exist). Despite there being no indication of these species on the main stem, care should be given by residents and developers within the Mill River to protect local ecosystems and species, recognized or not.

4.0 METHODS AND RESULTS OF GEOMORPHIC ASSESSMENT WORK

4.1 Fluvial Geomorphic and Bridge Assessments

The following sections summarize the stream stability assessments that were carried out on the Mill River in support of this River Corridor Management Plan.

4.1.1 Phase 1 Stream Geomorphic Assessment

A Phase 1 Stream Geomorphic Assessment looks at broad scale landscape data, historical data, and limited field reconnaissance to begin to understand watershed characteristics and potential stressors. A Phase 1 Geomorphic Assessment of the Mill River was completed in 2007 by the RRPC. The Phase 1 project report summarized the results of this work (Rutland County Planning Commission, 2007). The Phase 1 Assessment collected data from 59 subwatersheds. The study concluded that on these 59 reaches, floodplain modifications and land use changes were likely to have the greatest impact on stream stability (Figure 10).

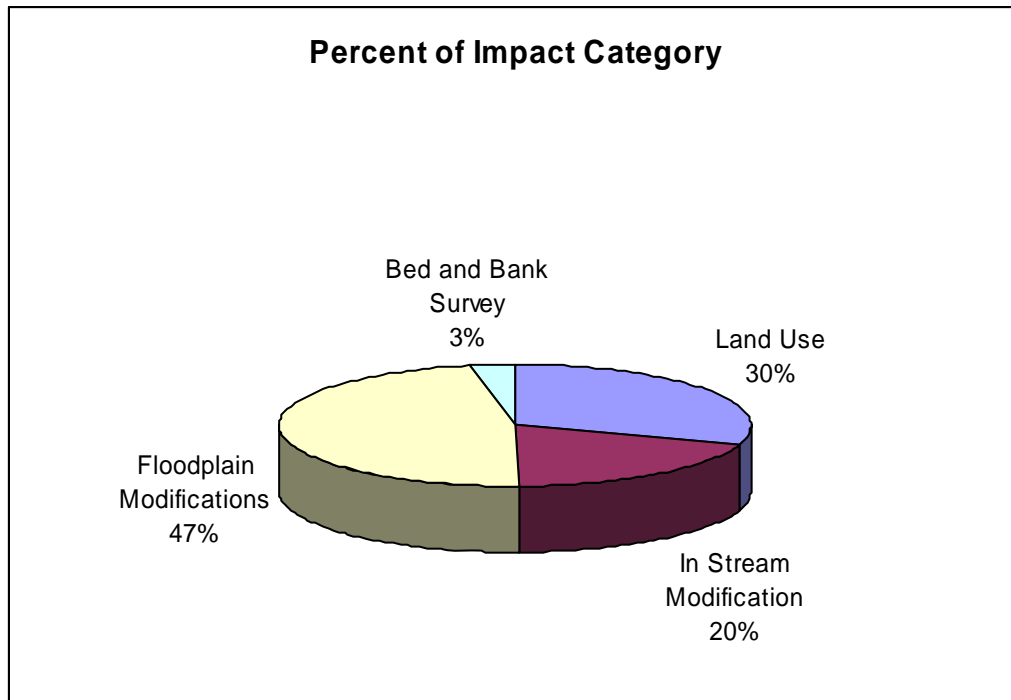


Figure 10: Mill River Phase 1 Impact Score results.



4.1.2 Phase 2 Stream Geomorphic Assessment

The Phase 2 Fluvial Geomorphic Assessment, conducted by RRD, followed procedures specified in the Vermont Stream Geomorphic Assessment Phase 2 Handbook (Vermont Agency of Natural Resources 2007b). The Phase 2 Assessment focused on the mainstem reaches starting above East Wallingford Village (M15) downstream to the mouth of the river. All assessment data were recorded on the Agency of Natural Resources Phase 2 field data sheets, and were entered in to the VTANR Stream Geomorphic Assessment online data management system (DMS) (<https://anrnode.anr.state.vt.us/ssl/sga/index.cfm>). The Phase 1 database was updated when necessary based on the field data collected during the Phase 2 assessment.

The Phase 2 study observed that the upper section of the Mill River in Mount Holly and East Wallingford has seen high amounts of historic channel straightening, floodplain encroachment, berming, and removal of riparian vegetation. There has been a collective loss of floodplain access due to berming, incision of the streambed, and floodplain encroachment. The result has been a loss of water and sediment storage in the upper watershed which has created an increase in river power during flood events resulting in instability and fluvial erosion hazards in these reaches. From the Upper Clarendon Gorge to the Lower Clarendon Gorge in the town of Shrewsbury the Mill River regains a sense of general stability aided by bedrock dominated channels. From the Lower Clarendon Gorge to the confluence with the Otter Creek in Clarendon the Mill River is a predictably dynamic stream in a natural area of sediment deposition (steeper narrow valley widens and flattens in a broader river valley). A recent study indicated that, “excessive sediment contributions and an apparent reduction in sediment transport capacity” were found in the Otter Creek at the Mill River confluence (Underwood 2006).

The most common adjustment processes observed in the Mill River during the Phase 2 Assessment were widening and planform migration as a result of degradation within the channel. A reach by reach summary of the Phase 2 data may be found in Appendix B.

4.1.3 Bridge and Culvert Analysis

The need to cross the Mill River via bridge is imperative. The act of placing a bridge over the river has historically involved constructing stone footers onto which rest timbers and later iron and steel. The footers (or abutments) were placed close enough together so that a single large timber could span from one side to the other. In a large stream such as the Mill River, these abutments were often narrower than the natural channel. Today, even with new materials, bridge crossings tend to be constructed narrower than the river channel. This narrowing of the river becomes problematic when, during high flows, floodwaters back up due to the constriction. This causes flooding upstream of the bridge. This is worsened by debris that can accumulate at a constricted area including sediment which can accumulate upstream at unnatural locations further exacerbating instability. During flood conditions, pressure is increased on the downstream side of the bridge (similar to placing one’s thumb on the end of a garden hose). The extra energy causes erosion and leaves a wide scoured area downstream of the bridge. Furthermore, physical changes to the river channel such as straightening and stone armoring leading up to and through a bridge, even in newer wider bridges, may prevent a river from migrating naturally across the valley bottom and may create fluvial erosion hazards.



In order to assess the impact of these crossings, bridge and culvert assessments were completed for all permanent structures located on Phase 2 reaches in accordance with Appendix G of the Phase 2 Geomorphic Assessment (2007b). Complete bridge and culvert assessment results can be found in Appendix C of this report. In total, fifteen structures were assessed according to VTANR protocols for such characteristics as specific height and width, geomorphic and fish passage data, nearby vegetation, and evidence of wildlife.

During the Phase 2 Assessment a number of bridge and culverts were observed to be considerably narrower than the existing bankfull width subsequently causing instability in the river (Table 2). Narrow crossings reduce sediment transport capacity and disconnect floodplains from the river channel. In particular need of replacement based on the problems observed and their percent bankfull width are the Route 155 Bridge in East Wallingford and the Barlow Road Bridge in Mount Holly. Also the two structures located on T2.01 were found to be undersized. From a technical measurement (from footing to footing) the railroad bridge on M11-A does not appear to be a problem, however, the channel width of the river from bridge abutment to the Route 155 embankment was only 39 feet (70% reference channel width) and should also be considered a problem structure (Figure 11).



Figure 11: The railroad bridge span on M11-A is adequate for the Mill River (red line), however, location of Route 155 in relation to the bridge and the river creates a channel constriction between the bridge abutment and the road (yellow line).



TABLE 2: MILL RIVER BRIDGES: PROBLEMS AND POTENTIAL FAILURE MODES																	
Reach	Road	Type	F1	F2	F3	F4	F5	F6	P1	P2	P3	P4	P5	P6	P7	Width	
M15	Private road	Bridge	-	-	-	X	-	X	X	X	X	X	-	-	X	111 %	
M14	BARLOW RD	Bridge	-	-	-	-	-	-	-	-	-	-	-	-	X	77 %	
M11-B	ROUTE 155	Bridge	-	X	X	X	X	X	-	X	X	-	-	-	X	54 %	
M11-A	Railroad	Bridge	X	-	-	X	-	X	X	-	-	-	-	-	-	190 %	
M10	ROUTE 140-EAST	Bridge	-	-	-	X	-	X	X	-	X	X	-	-	X	172 %	
M10	VILLAGE ST	Bridge	-	-	X	X	-	X	-	-	X	-	-	-	X	253 %	
M08	Railroad	Bridge	-	-	X	-	-	X	X	X	X	-	-	-	X	163 %	
M06	VT RTE 103	Bridge	-	-	-	-	-	X	-	-	-	-	X	-	X	171 %	
M05	VT RTE 103	Bridge	-	-	-	X	-	X	X	-	X	X	-	-	X	237 %	
M03-B	EAST ST	Bridge	-	-	X	-	-	-	-	X	-	-	-	-	X	85 %	
M01-B	ROUTE 7	Bridge	-	-	-	X	-	X	X	-	-	X	-	-	X	364 %	
M01-B	ROUTE 7	Bridge	-	-	-	X	-	X	X	-	-	X	-	-	X	364 %	
M01-B	Railroad	Bridge	-	-	-	X	-	X	X	-	-	X	-	-	X	154 %	
T2.01-B	BOWLSVILLE RD	Bridge	-	X	X	X	X	-	-	X	X	-	-	-	X	50 %	
T2.01-A	ROUTE 140-EAST	Bridge	-	X	X	X	X	X	X	X	-	X	X	-	X	61 %	
Failure Modes																	
F1	Concern for structure due to fluvial condition or process																
F2	Potential failure due to out-flanking																
F3	Potential failure due to scour																
F4	Potential failure due to ice or debris jam																
F5	Structure related damage due to flooding of adjacent property																
F6	Structure related damage due to erosion of adjacent property																
Existing Problems																	
P1	Upstream sediment deposit																
P2	Upstream Scour and/or erosion present																
P3	Downstream Scour and/or erosion present																
P4	Inlet obstruction present																
P5	Poor location or alignment																
P6	Beaver activity																
P7	Floodplain filled entirely or partially by roadway approaches																
Width	Structure width divided by channel width as a percent (% bankfull width)																

4.2 Quality Assurance (QA) Review

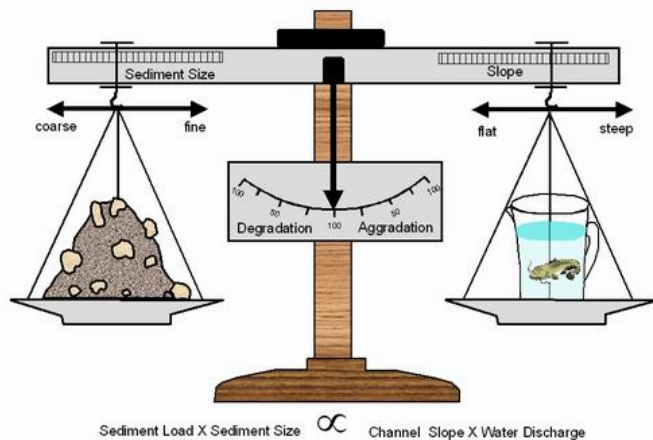
The Phase 1 and 2 Geomorphic Assessment and Bridge and Culvert Survey were carried out in compliance with the VTANR Programmatic QAPP (VTANR, 2003). Round River Design performed a thorough in-house quality assurance (QA) review of the Phase 2 data in November of 2007. The DMS and the ArcView Shapefiles for the Mill River Phase 2 study were submitted to Shannon Pytlik of the VTANR for a QA review in November of 2007. Shannon Pytlik completed the QA review during the first week of December, 2007. Mapping of existing



valley walls was conducted in support of fluvial erosion hazard zone development by the VTANR River Management Program.

5.0 FURTHER ANALYSIS: STRESSORS, CHANNEL RESPONSE, SENSITIVITY

The science of fluvial geomorphology informs us that given consistent inputs (average annual precipitation and sediment input), every stream has a single most probable form (width, depth, planform, slope) toward which it is constantly working (Leopold 1994). We also know that natural and anthropogenic impacts to a river channel or watershed may alter the equilibrium between sediment transport and water flow and may set in motion a series of morphological responses (aggradation, degradation, and widening and/or planform adjustment) as the river works to reestablish a self-maintaining stable channel (as depicted in Figure 12). It is important to recognize that all streams are consistently undergoing dynamic in-channel adjustments. Over time the bed level, location, and width of a channel may vary around a certain consistent “probable form”.



Under the right conditions, however, these equilibrium altering impacts (which may be small to moderate changes in slope, discharge, and/or sediment supply or large-scale changes) can exceed the threshold limit of a channel thereby causing a major shift in the form and equilibrium balance of the stream (Figure 13). These significant threshold exceedences may transform channel and floodplain interactions through entire reaches (up to several miles in length) (Ryan 2001).

Figure 12: Lane's Balance (1955) depicts how a change in sediment load, sediment size, channel slope, and/or the amount of water discharged may lead to channel degradation or aggradation.

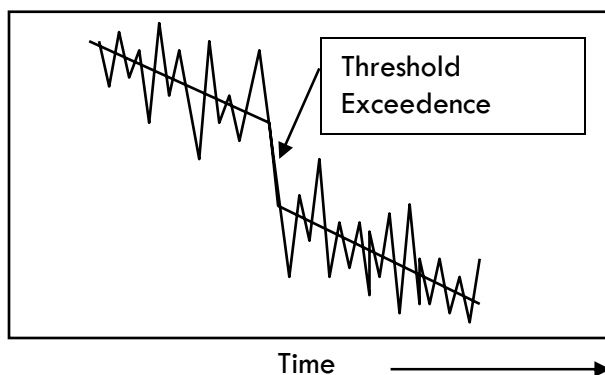


Figure 13: Threshold exceedences in dynamic stream channels. (Jaquith 2008)

Typically, channel adjustments fall into four major categories: degradation, aggradation, planform, and widening. Degradation (sometimes referred to as 'incision') is the term used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment in the channel. The planform is the channel configuration as seen from above. Planform change may be a reaction to channel straightening (Figure 14), or a channel response to other adjustments such as aggradation and widening. Channel widening occurs when



stream flows are contained in a channel as a result of degradation or floodplain encroachment or when sediments overwhelm the stream channel and the erosive energy is concentrated into both banks.

Analysis of the impacts that have led to changes in the sediment regime, hydrology, and channel configuration and dimensions of the Mill River, and therefore caused morphological adjustments such as those described above, is useful for informing restoration and planning efforts and is the focus of Section 5.1. Predicting how unstable river channels will react is the focus of Sections 5.2 and 5.3.

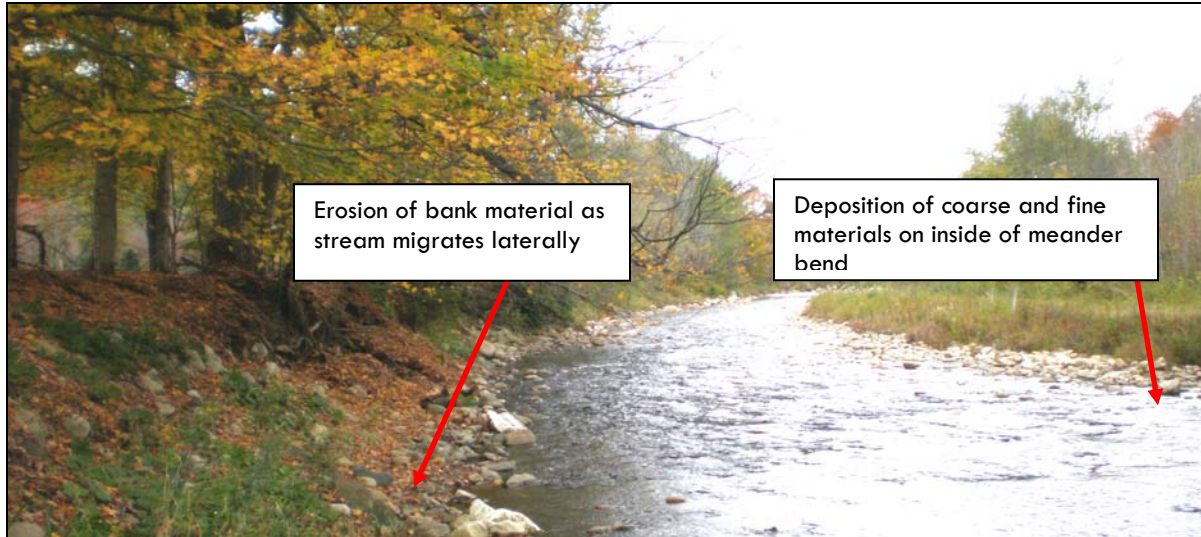


Figure 14: Planform migration associated with historic channel straightening of the Mill River.

5.1 Factors Influencing the Stability and Health of the Mill River

Appendix C is comprised of maps depicting some of the factors influencing the stability of the Mill River. Analysis of the map topics is provided below.

5.1.1 Alterations to the Hydrologic Regime of the Mill River

The hydrologic regime of a watershed refers to the timing, volume, and duration of runoff events that have, over time, influenced the shape and physical form of a river channel. Hydrology is influenced by climate, soils, geology, groundwater inputs, vegetation, riparian areas, and valley and stream shape. When the hydrologic regime of a watershed is significantly altered a river channel will adjust (e.g., increased stormwater flows result in consistently higher volumes of water passing through a channel and lead to channel degradation and incision).

While the significant deforestation that occurred in Vermont watersheds in the 19th century may still be influencing the Watershed, a number of more easily discernable hydrologic stressors are impacting the Mill River today. As depicted in Appendix A Figure 1, stormwater inputs from roads, field and road drainage ditches, and impervious surfaces are numerous in some reaches of the Mill River, particularly around the Villages of East Wallingford and Cuttingsville. These stormwater inputs hasten the timing and amount of water entering the



channel during a runoff event and may contribute to localized channel enlargement and flooding (as described in section 3.4).

Another significant impact to the hydrologic regime of the Mill River watershed may be alterations to the land use and land cover of the watershed. Specifically, the transition of land from forest to cropland and development, as well as the loss of wetlands causes a decrease in soil and floodplain storage and an increase in surface water runoff (Appendix A Figure 2). According to the VTANR River Corridor Planning Manual (VTANR 2007a), recent studies in Burlington and Saint Albans show that major channel adjustment and biological impacts are associated with watersheds that have over 5% impervious cover. The Phase 1 geomorphic assessment of the Mill River indicated numerous subwatersheds near or exceeding 5% urban and cropland cover indicating the possibility for major channel adjustment and biological impacts.

5.1.2 Alterations in the Sediment Regime of the Mill River

Understanding sediment transport and its role in stream stability and habitat is critical for successful river corridor planning and restoration. During high flows, small sediments are easily transported and deposited where low velocities are found (typically the inside of a bend or the floodplain). When floodplains do not exist or are inaccessible and where bends have been removed through straightening, fine sediments may be transported long distances until low velocities are met (such as the Otter Creek). As fine materials have the highest concentration of nutrients and organic material, the absence or overabundance of fine sediment in a stream system can have great impacts on the aquatic biology (VTANR 2007a).

Along the bottom of a stream the larger cobbles and gravels of a stream slide and tumble along during high water events. In a stable stream these larger particles are transported and sorted according to variations in stream power associated with slope, depth, and width. Disruptions in the transport of these larger particles either through increasing stream power (e.g. channel straightening, berming) or decreasing stream power (e.g. channel constricting bridges, gravel extraction) can have a significant affect on the stability and habitat of a stream and at worse may cause undesirable erosion and flood hazard issues.

Where excessive erosion, mass bank failures, rejuvenating tributaries, channel widening, and/or planform adjustments are occurring, sediment deposits are often formed as a river works to transport and redistribute these excessive sediment additions. Appendix A Figure 3 is a map depicting the number of sediment deposition features found in each reach of the study area. In the Mill River, higher rates of depositional features (e.g. gravel bars) are found in reaches with wide floodplains and some degree of unconstrained (i.e. not straightened, armored, and bermed) channel movement. Reaches locked into bedrock gorges or which have been artificially straightened tend to pass sediment through the channel rather than store it.

5.1.3 Modification of Channel Depth and Slope of the Mill River

Historic alterations of stream channels in post-flood cleanup efforts and for land use purposes have had great impacts on most Vermont Rivers. The Mill River is no exception. Impacts from channel straightening effect 15 reaches, six of which are over 75% straightened (Appendix A



Figure 4). Channel straightening increases the slope and therefore the power of a stream – this increase in stream power is typically followed by channel incision and eventually widening. Encroaching development onto the floodplain of the Mill River as well as berming to protect this development is also problematic. Berming and floodplain fill (for roads, railroads, and development) effectively raises the bank height, which increases channel depth, and thereby increases the erosive power of the stream. Increased erosive power creates a detriment locally as well as increases the potential for catastrophic fluvial erosion downstream (see Appendix E). Floodplain encroachment is a common phenomenon along the Mill River as depicted in Appendix A Figure 5.

5.1.4 Modification of Streambank and Riparian Conditions along the Mill River

The material (cohesiveness) of the banks as well as the naturally occurring vegetation that binds soils has a tempering affect to resist the erosive energy of a stream. Changes in the condition of a streambank from such activities as riparian vegetation removal and rock armoring may increase stream power resulting in channel adjustments such as widening and planform adjustment. Riparian forests that have been reduced to less than 25 feet in width are depicted in Appendix A Figure 6.

5.1.5 Constraints to Sediment Transport and Attenuation

The analysis of sediment transport regimes is based on methodology outlined in the VTANR River Corridor Planning Guide (2007a) which assists in the identification of the reference and altered sediment regimes of reaches based on the Phase 2 Assessment data. The sediment regime types used in this analysis are summarized in Table 3. Figures 15 and 16 have been provided to assist in understanding where sediment transport areas have been increased and attenuation areas have been lost in the Mill River Watershed. Table 4 has also been provided to summarize all of the stream and watershed stressors and to assist in understanding why these changes in sediment transport capacity have occurred.

Figure 15 indicates that nearly the entire main stem of the Mill River had (in its pre-settlement state) the capacity to store fine sediments in the floodplain and to transport the normal balance of gravels, cobbles, and the occasional boulder downstream at a rate that was in balance with the inputs coming from the highest sources in the watershed thus leading to long-term channel and habitat stability. Analysis of Figure 16, the current sediment regime map, indicates that *nearly all reaches in the Mill River watershed are now sources of both fine and coarse materials and that storage of fine materials in the floodplain has been significantly reduced*. In areas where deposition of coarse materials is occurring in the upper watershed this deposition may be occurring at a high rate (leading to numerous mid-channel bars and channel migration and subsequently a local response of dredging this accumulating material) such as was observed in reaches M11-B and M06. The cumulative effect of this sediment storage loss has been an overloading of sediment in the receiving body, the Otter Creek. As indicated in a Phase 2 assessment of the Otter Creek, “Excessive sediment contributions and an apparent reduction in sediment transport capacity are noted in the vicinity of the Mill River confluence with the Otter Creek.” It is a concern that this sediment may “tip the balance” of stable conditions in the Otter Creek if left unchecked (Underwood 2006).



The excessive degree of departure in the upper watershed presents two situations downstream. First, the downstream reaches may be moving towards excessive aggradation of material (such as in reach M05-A) and therefore may be expected to have a high degree of lateral channel adjustment and bar building. Second, the storage capacity of these downstream reaches is a key asset to the watershed and the receiving watershed, the Otter Creek (and eventually Lake Champlain). Analysis of these maps reveals that restoration of attenuation capacity in the upper reaches of the watershed, especially above the village locations of East Wallingford and Cuttingsville, may be helpful in restoring some of the overall equilibrium of the Mill River Watershed and reducing pressure on those areas where significant human investment has been concentrated (such as the village settings).

TABLE 3: Sediment Regime Definitions

Transport	Steep bedrock and boulder cascade type streams; confining valley walls, comprised of bedrock, till, and large glacial erratics, do not supply appreciable quantities of sediments to downstream reaches on an annual basis; little or no mass wasting; storage of fine sediment is negligible due to high transport capacity derived from both the high gradient and/or entrenchment of the channel.
Confined Source and Transport	Cobble step pool and steep plane bed type streams; confining valley walls, comprised of erodible tills, glacial lacustrine, glacial fluvial, or alluvial materials; mass wasting and landslides common and may be triggered by valley rejuvenation processes; storage of coarse or fine sediment is limited due to high transport capacity derived from both the gradient and entrenchment of the channel. Look for streams in narrow valleys where dams, culverts, encroachment (roads, houses, etc.), and subsequent channel management may trigger incision, rejuvenation, and mass wasting processes.
Unconfined Source and Transport	Sand, gravel, or cobble plane bed type streams; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to entrenchment or incision and associated bed form changes; these streams are not a supply of sediments due to boundary resistance such as bank armoring, but may begin to experience erosion and supply both coarse and fine sediment when bank failure leads to channel widening; storage of coarse or fine sediment is negligible due to high transport capacity derived from the deep incision and little or no floodplain access for the channel. Look for straightened, incised or entrenched streams in unconfined valleys which may have been bermed and extensively armored and are in Stage II or early Stage III of channel evolution.
Fine Source and Transport Coarse Deposition	Sand, gravel, or cobble streams with variable bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to vertical profile and associated bed form changes; these streams supply both coarse and fine sediments due to little or no boundary resistance; storage of fine sediment is lost or severely limited as a result of deep channel incision and little or no floodplain access; an increase in coarse sediment storage occurs due to a high coarse sediment load coupled with the lower transport capacity that results from a lower gradient and/or channel depth. Look for historically straightened, incised or entrenched streams in unconfined valleys, having little or no boundary resistance, increased bank erosion, and large unvegetated bars. These streams are late Stage III and Stage IV of channel evolution.
Coarse Equilibrium (in = out) Fine Deposition	Sand, gravel, or cobble streams with equilibrium bed forms; at least one side of the channel is unconfined by valley walls; these streams transport and deposit coarse sediment in equilibrium (stream power—produce as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance); storage of fine sediment as a result of floodplain access for high frequency (annual) floods. Look for unconfined streams which are not incised or entrenched, have boundary resistance (woody buffers), minimal bank erosion, and vegetated bars. These streams are Stage I, late Stage IV, and Stage V of channel evolution.

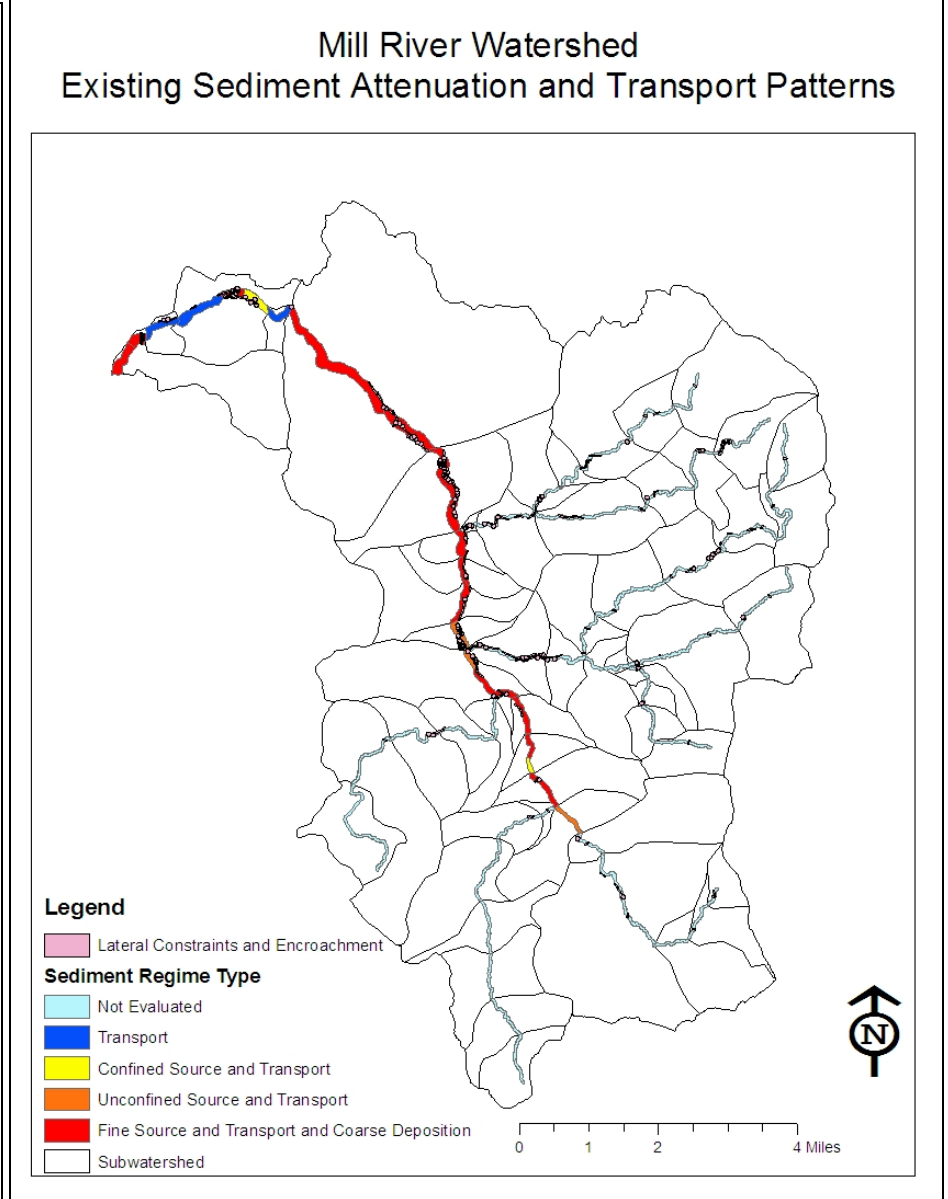
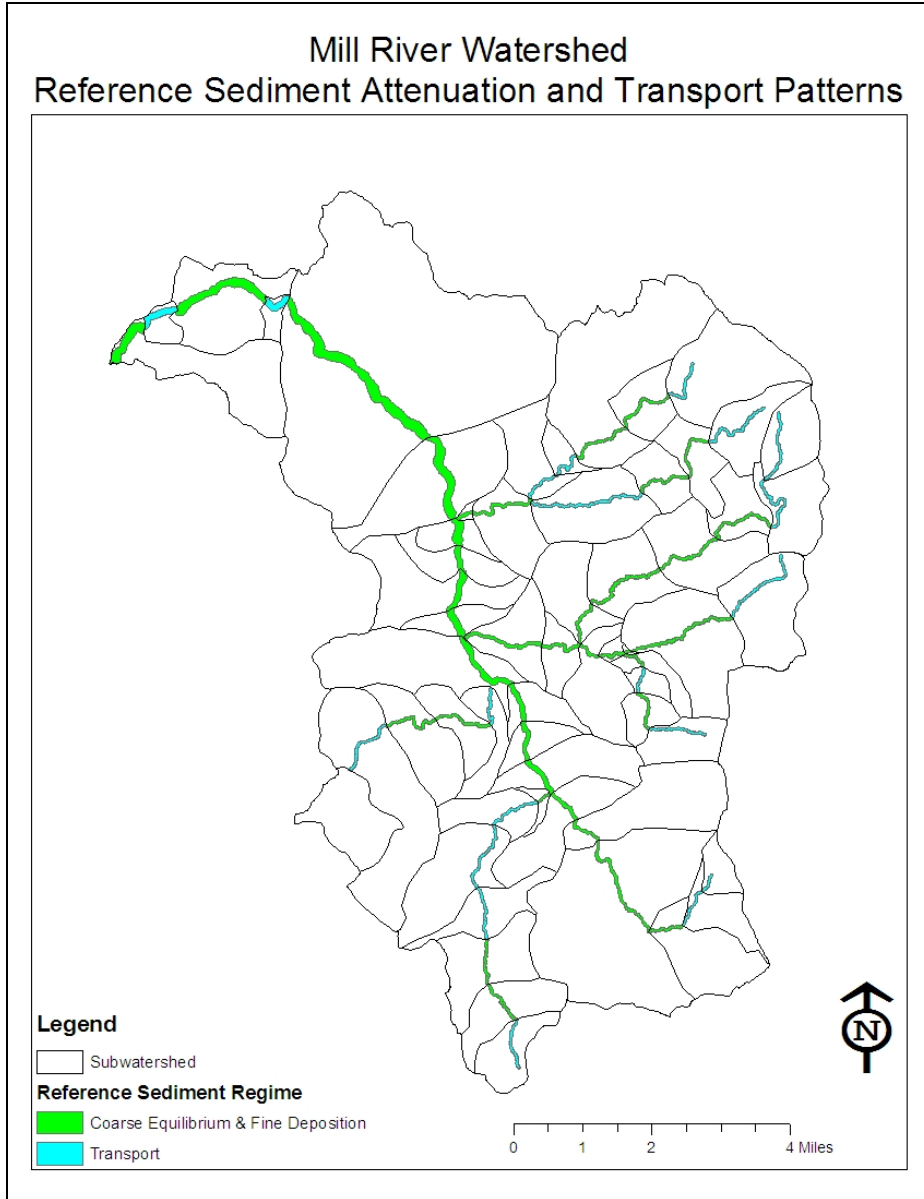


Figure 15. Sediment Transport and Attenuation under reference conditions.

Figure 16. Sediment Transport and Attenuation, existing Mill River conditions.



Table 4: Watershed, Floodplain, and Channel Stressors

Segment Number	Watershed Stressors			Floodplain and Channel Stressors									
	Deforestation in the 1800's	Increased Road Networks (1800-1900's)	Historic Flood Events	Channelization/Straightening	Dredging	Berming	Bank Armoring	Floodplain Development	Loss of Forested Buffers	Impoundment (Historic)	Gravel Extraction	Undersized Bridge/Culvert	Stormwater Inputs
M15				√		√			√				√
M14				√			√		√			√	√
M13-B													√
M13-A													
M12													√
M11-B				√	√		√		√		√		√
M11-A				√	√	√	√	√	√			√	√
M10				√	√	√	√	√	√			√	√
M09				√	√	√	√	√					
M08				√			√	√					√
M07				√	√	√		√	√				
M06				√	√	√	√	√	√	√			√
M05-B				√	√	√	√	√	√				√
M05-A				√	√		√						√
M04													
M03-C									√				
M03-B									√	√			√
M03-A													
M02													
M01-B				√	√	√	√	√	√		√		
M01-A				√	√				√				
T2.01-B							√	√				√	
T2.01-A				√	√	√	√	√	√			√	



5.2 Understanding Channel Response to Disturbance

The information presented in section 5.1 indicates that a large number of watershed and channel stressors are potentially affecting the Mill River. Because the stability of a stream channel is based on maintaining a certain flow of water and sediment and shape and slope of the channel, when any of these change significantly, the river channel must change, typically resulting in erosion of the stream bed or banks, or a filling of the channel with sediment.

As a result of channel straightening, berming, gravel mining, stormwater runoff, and similar watershed and reach alterations, we may conclude that stream power has increased within the Mill River channel. One of the most common channel responses to an increase in stream power is degradation. Once a stream begins to incise, it will typically erode its way through a predictable evolution process until it has created a new floodplain at a lower elevation in the landscape. The common stages of channel evolution (as shown below in Figure 17 and reported in more detail in Appendix D), include:

- A pre-disturbance period (I)
- Incision – Channel degradation (cutting of stream into the channel bed) (II)
- Aggradation (sediment build up in the bed) and channel widening (III-IV)
- The gradual formation of a stable channel with access to its floodplain at a lower elevation. (V)

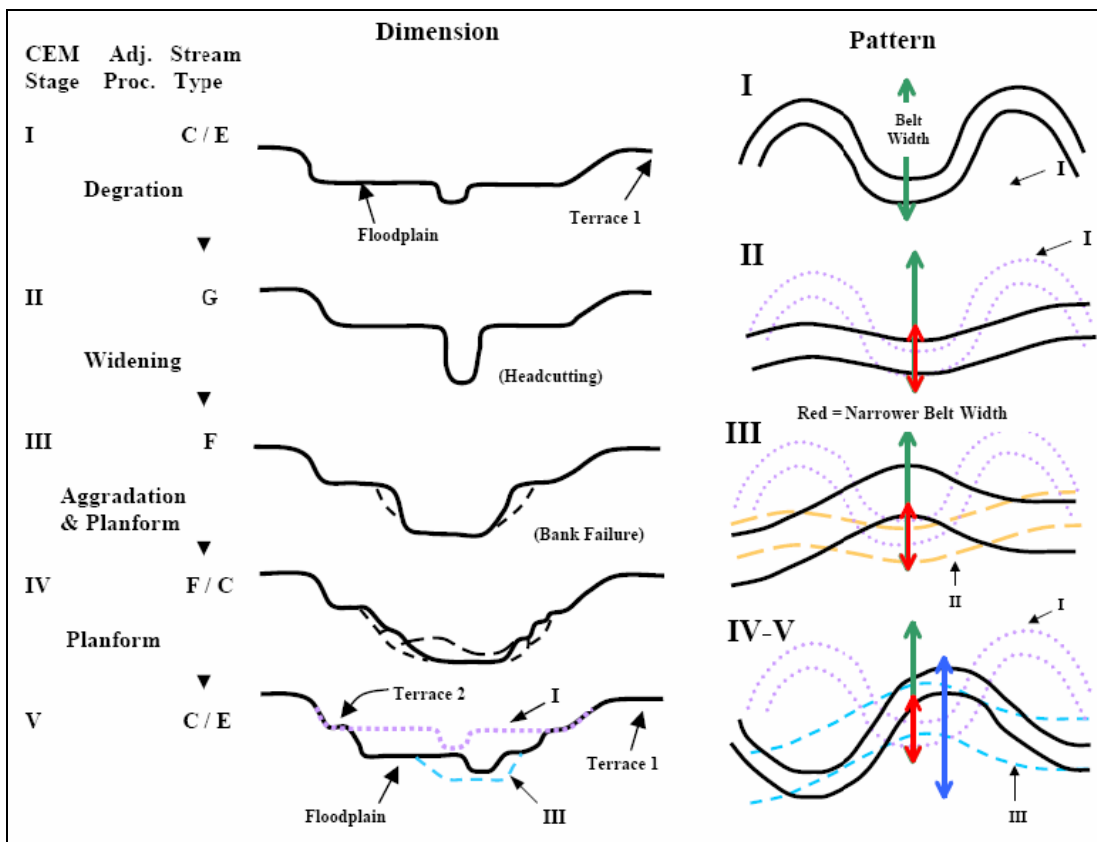


Figure 17. F-stage Channel Evolution Process (from Vermont Agency of Natural Resources, 2006)

The bed erosion that occurs when a meandering river is straightened in its valley is a problem that often extends to other sections of the stream. Incision points will travel upstream and into



tributaries eroding sediments from otherwise stable streambeds. These bed sediments will move into and clog reaches downstream leading to planform adjustments, widening, and erosion of the streambanks. Channel evolution processes may take decades to play out and may not only affect areas immediately adjacent to evolving channels. Even landowners that have maintained forests along their stream and riverbanks may experience eroding banks, sedimentation, and migrating channels, as the river responds to alterations up or downstream (such as the case with reaches M13-A, M12, and M05-A). Furthermore, consistent changes in the location of a river channel are expected as rivers have always and will always continue to migrate laterally across valleys; this migration is often unperceivable to the human eye, however, is sometimes catastrophically rapid (see Figure 18).

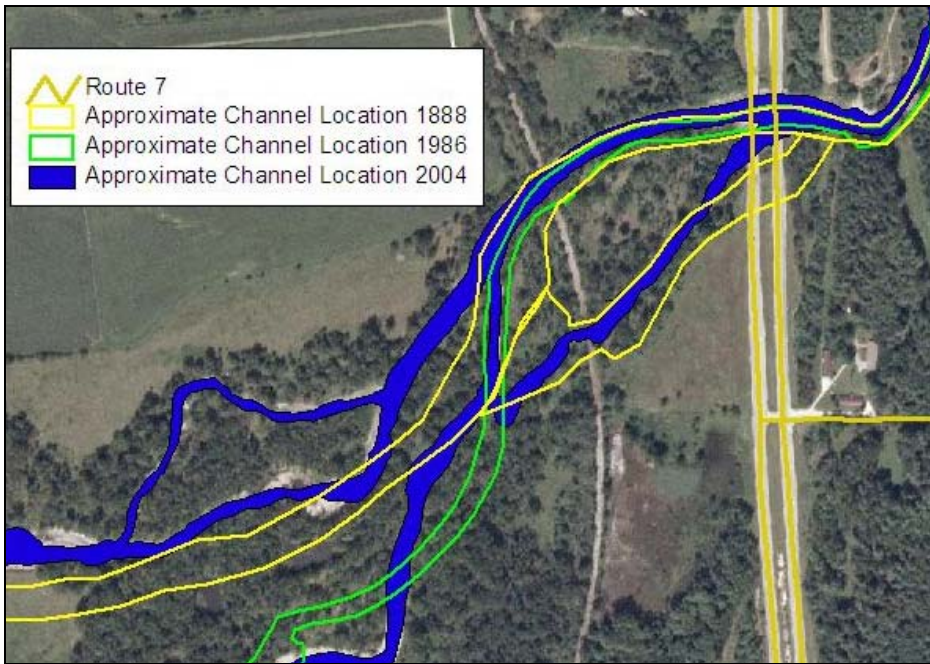


Figure 18: Meander patterns in the lower Mill River in Clarendon.

After a channel incision process it may be difficult for streams to attain equilibrium where the placement of roads and other infrastructure has resulted in little or no valley space for the stream to access or to create a floodplain as is the case with many of the Mill River's reaches (e.g. M09, M11-A). Making matters worse, landowners and government agencies have repeatedly armored and bermed many of Vermont's rivers to contain floodwaters in channels. These efforts have proven to be temporary fixes at best, and in some cases have led to disastrous property losses and natural resource degradation.

Field research conducted during the Phase 2 assessment indicated that several of the reaches are actively, or have historically, undergone a process of minor or major geomorphic adjustment. In many reaches the channel has undergone historic degradation as evidenced by abandoned terraces, juvenile floodplain benches, and rejuvenating tributaries. Many of the cross sections on study reaches were found to be incised. The incision ratio ranged from 1.5 to 3.1. Along many of the main stem reaches and near the mouths of the tributaries, the system is currently actively adjusting to this lower bed elevation by moving laterally (planform) and widening in order to create a new floodplain at a lower elevation (phase II, III, and IV of the channel evolution model depicted in Figure 17). This widening and planform adjustment is



leading to another adjustment process, aggradation. Aggradation in the Mill River study area is likely a combination of endogenous sediment that is created as the stream widens and erodes its banks in response to channel adjustments as well as from exogenous sources such as gravel roads and land clearing. Table 5 below summarizes the channel evolution of each study reach and the primary adjustment processes that are believed to be occurring.

Table 5. Stream Type, Active Adjustment Processes*, and Channel Evolution Stage							
Segment Number	Incision Ratio	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
M15	2.08	2.18	17.09	C4	B3c	III	None
M14	3.16	2.0	20.51	C3b	B3	III	Widening
M13-B	1.97	1.75	27.83	B3	B3	III	None
M13-A	1.85	5.83	28.17	C4	C4	IV	Planform
M12	1.89	4.88	30.48	C4	C4	IV	Widening Planform
M11-B	2.33	1.54	29.74	C4	B3c	III	Aggradation Widening Planform
M11-A	3.19	1.37	36.00	C4	F3c	II	Widening
M10	1.80	2.14	22.11	C4	B3c	III	None
M09	1.84	1.28	39.55	C4	B3c	III	Widening
M08	1.90	3.47	25.35	C3	C3	III	None
M07	1.65	1.29	45.79	C4	F4	III	Widening
M06	1.84	6.10	32.06	C4	C3	III	Widening Planform
M05-B	1.74	1.79	35.33	C4	B3	III	Widening
M05-A	1.57	4.76	26.84	C4	C4	IV	Planform
M04	Not Assessed: Bedrock Controlled Gorge						
M03-C	1.61	1.74	33.74	B4	B4	III	Widening
M03-B	Not Assessed: Bedrock Controlled Gorge						
M03-A	1.55	5.24	38.89	C3	C3	IV	Widening
M02	Not Assessed: Bedrock Controlled Gorge						
M01-B	1.83	5.00	36.02	C4	C3	III	Widening Planform
M01-A	1.95	10.8	54.44	C4	C4	IV	Aggradation Widening Planform
T2.01-B	1.93	1.93	26.98	C4	B4c	IV	Planform
T2.01-A	2.29	1.3	25.6	C4	F3c	II	Widening
<p>Bold Red lettering - denotes extreme adjustment process Bold Black lettering – denotes major adjustment process *NOTE: All reaches except M01-A, M03-A, M03-C, and M13-B had major or extreme historic degradation</p>							



5.3 Stream Sensitivity

As Section 5.1 described, there are numerous watershed and reach-level stressors that have affected the Mill River. In response, the Mill River has undergone and continues to undergo reasonably predictable channel adjustments as described in section 5.2. As we move towards managing restoration and future development in the Mill River watershed it is important to understand that certain areas of the river may be more or less sensitive to management and development activities in the channel and floodplain. “Stream sensitivity” refers to the likelihood that a stream will morphologically respond to a watershed level or reach level stress, such as; floodplain encroachment, channel straightening, berming, armoring, changes in sediment or flow inputs, disturbance of riparian vegetation, and even in-channel restoration efforts meant to stabilize the channel. A stream’s inherent sensitivity is based on a host of factors including the relative magnitude of channel adjustments occurring together with the topographic, geologic, and vegetative context that surrounds the reach. The existing sensitivity of a given reach may be increased when human activities alter the characteristics that influence a stream’s natural adjustment rate including changes to the: boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive to stress (Vermont Agency of Natural Resources 2007a).

In Vermont, it can be generalized that steeper mountain streams with large bottom substrates (boulders and cobbles) are less sensitive to rapid channel adjustment than those gravel and sand dominated stream channels that have low slopes (<3%) and therefore less ability to transport sediments received from upstream. These more sensitive channels often have highly-erodible soils and are more sensitive to increases and decreases in stream power that may occur from channel and floodplain alterations and/or changes in sediment supply (increase or decrease) (Underwood 2006).

The stream sensitivity of the Mill River, categorized by segment according to ANR protocols, is depicted in Table 6 and in Figure 19. Predominately, the Phase 2 Geomorphic Assessment purposefully studied reaches that would be expected to exhibit a higher sensitivity and be undergoing active adjustments. It is not surprising therefore that all of the study area reaches were defined as having high, very high, or extreme sensitivity. The exception being the bedrock controlled reaches M04, M03-B, and M02 which have a greater resistance to rapid adjustment due to the bedrock bed and banks (and therefore a low sensitivity).

Incorporating stream sensitivity data into management and restoration activities is critical. In general, highly sensitive stream types should be approached with great caution before engaging in direct in-channel restoration activities. Often these highly sensitive reaches may be better protected by reducing upstream, in-channel, and corridor stressors. Less sensitive channels may be better candidates for in-stream channel restoration activities and floodplain restoration projects as these channels tend to have a high tolerance for change.



Table 6. Stream Sensitivity for Phase 2 Reaches					
Segment Number	Reference Stream Type	Existing Stream Type	Stream Type Departure	Geomorphic Condition	Sensitivity
M15	C4	B3c	C to B	Fair	High
M14	C3b	B3	C to B	Fair	High
M13-B	B3	B3	None	Good	High
M13-A	C4	C4	None	Fair	Very High
M12	C4	C4	None	Fair	Very High
M11-B	C4	B3c	C to B	Fair	High
M11-A	C4	F3c	C to F	Fair	Extreme
M10	C4	B3c	C to B	Fair	High
M09	C4	B3c	C to B	Fair	High
M08	C3	C3	None	Fair	High
M07	C4	F4	C to F	Fair	Extreme
M06	C4	C3	None	Fair	High
M05-B	C4	B3	C to B	Fair	High
M05-A	C4	C4	None	Fair	Very High
M04*	B1	B1	None	Good	Very Low*
M03-C	B4	B4	None	Fair	High
M03-B*	B1	B1	None	Good	Very Low*
M03-A	C3	C3	None	Fair	High
M02*	B1	B1	None	Good	Very Low*
M01-B	C4	C3	None	Fair	Very High
M01-A	C4	C4	None	Fair	Very High
T2.01-B	C4	B4c	C to B	Fair	Very High
T2.01-A	C4	F3c	C to F	Fair	Extreme
*Partial Assessment – Administrative judgment made regarding geomorphic condition and sensitivity					



Mill River Watershed Stream Sensitivity Ratings

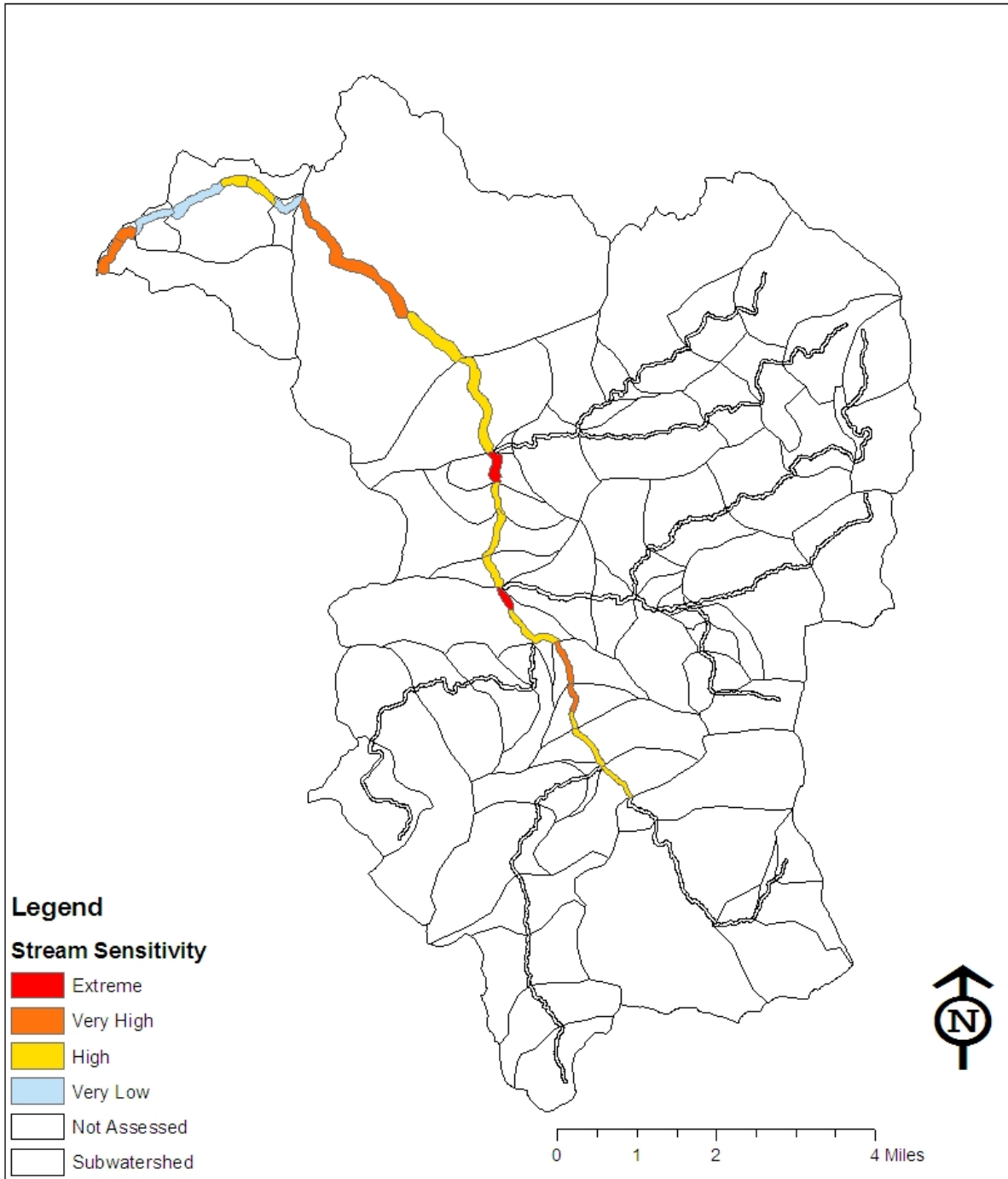


Figure 19: Mill River Stream Sensitivity Map



6.0 PROJECT IDENTIFICATION

As outlined in the preceding sections, riparian landowners, community members, town planners, and agency personnel from State and Federal resource groups would all benefit from having a holistic perspective of watershed processes and the stressors that lead to instability in these systems. Concurrently, knowledge and awareness of factors that lead to stream stability is also desired. The objective of this management plan is to consider these complex interactions with an eye toward implementing various restoration, conservation, and planning activities for the long term benefit of the community.

Recommended corridor restoration and protection initiatives have been identified based on the synthesis of: the project and program goals (Section 2.0); wealth of current and historic watershed information (Section 3.0); field based observations (Section 4.0 and summarized for each reach in Appendix B); and on the remotely-sensed observations of channel and floodplain stressors (Section 5.1). This data was processed to determine stream types, adjustment processes, and channel evolution stages (Section 5.2). From this information, the sensitivity of each reach and segment was derived (Section 5.3). And here finally a step-wise procedure for identifying projects which would be consistent with the goal of managing a stream toward equilibrium condition (VTANR 2007a) was enacted.

It should be noted that, while the focus of this report has been on developing management decisions based on geomorphic information, social and fiscal opportunities must be taken into account as should be landowner interests. Adding this information to the equation may present possibilities for collaborative and synergistic projects not envisioned within this document. Recommended initiatives have been prioritized according to urgency. Many of the recommendations (e.g., buffer plantings) can be considered for immediate implementation, independent of other watershed projects.

6.1 Watershed Level Opportunities

Often many reach level problems may be best addressed through watershed-level, community-initiated strategies that seek to address the 'source' of a problem and consider that in watersheds, top-down problem-solving is often the only long-term solution. These large-scale watershed efforts may be initiated through local governments and/or community organizations, such as the Upper Otter Creek Watershed Council. They may also be embraced and driven by local residents that are inspired through demonstration projects or other outreach efforts.

Watershed scale strategies that would benefit the Mill River include:

- The establishment and protection of riparian buffers along the entire river corridor.
- On-site stormwater management retrofitting for all existing residential and commercial building sites and implementation of low-impact design (LID) techniques for all future development.
- Sound municipal dirt road management and ditch remediation for minimizing stormwater and sediment contamination of the Mill River.
- Replacing and/or retrofitting undersized bridges and culverts and ensuring all new structures are sized for geomorphic stability.
- Practicing soil conservation and erosion control practices (AMP's and BMP's) on all agricultural land, logging operations, construction and other sites where soil is disturbed.



- Floodplain and river corridor planning and protection (such as adoption of Fluvial Erosion Hazard zones, stream setbacks, wetland regulations, etc.) to reduce further floodplain encroachment.
- Wetland restoration projects that reduce stormwater volumes and increase groundwater and subsurface recharge rates.

6.2 Reach Level Projects

Reach level projects are based on conditions specific to the given reach, though they are also considered in the context of upstream and downstream impacts. These projects are especially appropriate where the disturbance extends along the entire reach and/or where land ownership is dominated by a few key stakeholders that are able to easily enact large-scale land management decisions. This River Corridor Management Plan includes detailed descriptions of individual reaches (Appendix B) as well as the identification of reach-specific projects (Table 7).

6.3 Site Specific Project Priorities

Site specific projects were distinguished from reach level opportunities utilizing guidance from the VTANR River Corridor Planning Guide (2007a). Compiling information from a step-wise analysis of each reach along with field observations collected during the Phase 2 Assessment, Round River Design, Bear Creek Environmental, and representatives from the RNRCD and VTANR identified 13 site specific priority projects (Table 8). These projects have been briefly evaluated for technical, social, and financial feasibility. Further analysis of these sites was conducted by Bear Creek Environmental and may be available through the local office of the VTANR River Management Program.

The selected projects include: river corridor protection projects in strategic locations; berm removal projects; and feasibility studies for the removal of undersized structures. It is important to note that these projects affect private landowners. The RNRCD and the VTANR are looking for landowners to partner with in order to implement these important projects.

7.0 NEXT STEPS AND IMPLEMENTATION

7.1 Single and Multiple Landowner Project Implementation

In October of 2008, Bear Creek Environmental, the Rutland Natural Resource Conservation District and other project partners began to meet with Mill River landowners to discuss the results of this plan. While historic stream protection efforts have focused on addressing individual landowner concerns, it is the hope of the watershed planning team that this document will help landowners see their land in a watershed context. Certain restoration and protection measures may be highly influenced by upstream challenges as well as may be highly important in reducing problems transferred to downstream landowners. The key to developing a mutually beneficial relationship with the Mill River is implementing future restoration and protection efforts with a watershed system in mind. The goal is that the Mill River will be managed to achieve a dynamic, geomorphically-stable stream channel in the future that is able to attenuate and transport its sediments in balance; access floodplains adequately without causing significant



damage to property or life; and maintain a healthy ecology and acceptable water quality for future generations to enjoy.

7.2 Watershed Resident Participation

Despite the efforts that may be made towards site specific river restoration projects, the long-term health and vitality of the Mill River is also intimately linked to the residents of the Watershed and whether they choose to collectively engage in land use practices that care for the river. Strategies that provide incentives for landowners and residents to engage in land stewardship may be effective since in the Mill River every resident has a neighbor downstream that may be affected by their actions. Community-based watershed associations have a long history of successfully implementing grassroots initiatives that bolster local watershed stewardship. Such an organization may prove highly beneficial to the long-term management of the Mill River. Additionally, town projects that ensure public access to the river may be important in developing connections between the river and the community. At the same time, educational efforts that create connections with the community youth and the watershed have also been found to be valuable in developing a long-term watershed stewardship ethic and sense of place.

7.3 Town and State Implementation

Implementation of the Mill River Corridor Management Plan will greatly rely on the inherent ability of Towns and the State to garner expertise and funding. It will be important for Towns and the State to develop strong collaborative relationships with streamside landowners.

At the town level, priority opportunities include:



- Management of town roads, culverts, crossings, and ditches in ways that protect water quality, prevent excess sediment from entering the Mill River, and allow the river and streams that feed it to pass under roads without creating instability in the streams.
- Adoption of town land use policies that prevent wetland loss, floodplain encroachment, and the further restriction of the Mill River (see Appendix E).

At the state level, priority opportunities include:




- Provision of scientifically informed data and management recommendations.
- Support of landowner initiatives through program recommendation and/or permitting that encourages beneficial restoration and protection efforts to move forward.



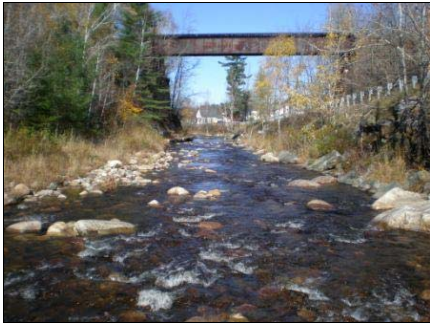

TABLE 7: Reach Level Projects

REACH NUMBER	METHOD	BENEFIT	DESCRIPTION	FEASIBILITY/ CONSTRAINTS	COST	LANDUSE CONVER- SION	PARTNERS
M15 	Protect River Corridor	Upstream of Constrained/ Altered Reach	Reach M15 lies upstream of the constrained and channelized reach M14 as well as those near East Wallingford Village	No major structures along river	Unk.	Open land and forest remains structure free	Town, RRPC, VTANR
	Restore Riparian Buffer	Long term stability	Buffer removal on the left bank has made this reach vulnerable in the long-term.	No major structures along river. River may remain stable for years to come and allow trees to grow.	Low	Agriculture and Residential Land to Forest	UOCWC, RNRCD, FWS
	Restore Incised Reach	Reduce flooding downstream, store sediment in the floodplain	Possible site for restoring floodplain access to improve flood and sediment load attenuation and take pressure off of downstream reaches.	Depends on method of restoration. No major structures along stream.	High	Agricultural land to floodplain	VTANR
M14 	Protect River Corridor	Upstream of Constrained/ Altered Reach	Reach M14 lies upstream of the constrained and altered reaches near East Wallingford Village	Only one house along river. Out of floodway and FEH zone.	Unk.	Open space with one residence is not developed further	Town, RRPC, VTANR
	Restore Riparian Buffer	Long term stability	Buffer removal on the left bank has made this reach vulnerable in the long-term.	No major structures along river. River may remain stable for years to come and allow trees to grow.	Low	Open Land to Forest	UOCWC, RNRCD, FWS
	Restore Incised Reach	Reduce flooding downstream, store sediment in the floodplain	Possible site for restoring floodplain access to improve flood and sediment load attenuation and take pressure off of downstream reaches.	Depends on method of restoration. No major structures along stream.	High	Open land to floodplain	VTANR





REACH NUMBER	METHOD	BENEFIT	DESCRIPTION	FEASIBILITY/ CONSTRAINTS	COST	LANDUSE CONVER- SION	PARTNERS
M13-A 	Protect River Corridor	Sediment Attenuation Area (Conserve and Enhance)	This fairly undeveloped reach is already attenuating floodwaters and sediment. Long term river corridor protection would reduce future conflict and ensure these functions are served for future generations.	No structures near the river.	Unk.	None, remains forest	Town, RRPC, VTANR
M12 	Protect River Corridor	Sediment Attenuation Area (Conserve and Enhance)	This fairly undeveloped reach has capacity for attenuating floodwaters and sediment. Long term river corridor protection would reduce future conflict and ensure these functions are served for future generations.	No structures near the river.	Unk.	None, remains forest	Town, RRPC, VTANR
M11-B 	Protect River Corridor	Upstream of Constrained/ Altered Reach	Reach M11-B lies upstream of the constrained and altered reaches of those near East Wallingford Village	Agricultural land, but no significant structures along river corridor.	Unk.	None, remains agricultural land.	Town, RRPC, VTANR, NRCS





REACH NUMBER	METHOD	BENEFIT	DESCRIPTION	FEASIBILITY/ CONSTRAINTS	COST	LANDUSE CONVER- SION	PARTNERS
M11-B (cont.)	Restore Riparian Buffer	Long term stability	Buffer removal on the right bank has made this reach vulnerable in the long-term.	No major structures along river. Channel is incised and will likely widen over time.	Low	Agricultural Land to Forest	UOCWC, RNRCD, FWS
	Restore Incised Reach	Reduce flooding downstream, store sediment in the floodplain	Possible site for restoring floodplain access to improve flood and sediment load attenuation and take pressure off of E. Wallingford Village reach.	Depends on method of restoration. No major structures along stream.	High	Open land to floodplain	VTANR
M11-A 	Protect River Corridor	Inform Residents of FEH Hazards and Reduce FEH Hazards	This is an already highly settled area and residents should be made aware of Fluvial Erosion Hazards. The reach is highly sensitive and has a major departure from equilibrium conditions.	Numerous existing structures	Unk.	Remains residential	Town, RRPC, VTANR
	Restore Incised Reach	Reduce flood hazard in East Wallingford Village	Possible site for restoring floodplain access to improve flood and sediment load attenuation and take pressure off of downstream reaches.	May only be possible in small zone on left bank.	High	Forest to floodplain.	VTANR
	Restore Riparian Buffer	Improve shade, stability of river, habitat	Buffer has been removed along a good portion of right bank due to armoring along the road.	Very little room for reforestation	Low	Barren to forest	VTANR, RNRCD
M10 	Protect River Corridor	Reduce FEH Hazards	This is a highly sensitive reach with a major departure from equilibrium conditions near a residential area.	Numerous existing structures	Unk.	Remains residential	Town, RRPC, VTANR
	Restore Riparian Buffer	Improve shade, stability of river, habitat	Buffer has been removed along a good portion of right bank due to armoring along the road.	Very little room for reforestation	Low	Barren to forest	VTANR, RNRCD





REACH NUMBER	METHOD	BENEFIT	DESCRIPTION	FEASIBILITY/CONSTRAINTS	COST	LANDUSE CONVERSION	PARTNERS
M09 	Protect River Corridor	Upstream of Constrained/ Altered Reach	Reach M09 lies upstream of the constrained and altered reaches of Cuttingsville Village	Some existing structures.	Unk.	Prevention of further development in the corridor.	Town, RRPC, VTANR
	Berm Removal Site	Improve floodplain access by removing bermed material.	Large berm on the lower end of the reach (right bank) may be removed or relocated.	Road along right corridor needs to be protected.	Med.	Remains forested land.	VTANR
M07 	Protect River Corridor	Upstream of Constrained/ Altered Reach with existing FEH Hazards.	Reach M07 lies upstream of the constrained and altered reaches of Cuttingsville Village. This is a highly sensitive reach with a major departure from equilibrium conditions near a residential area.	A few structures near corridor.	Unk.	Potential restriction on landuse depending on agreement.	Town, RRPC, VTANR
	Berm Removal Site	Removing berms would open a large section of floodplain back up.	Possible berm removal project, land conservation to public land.	A few structures near corridor need to be protected.	Mod.	Opening up the floodplain.	VTANR


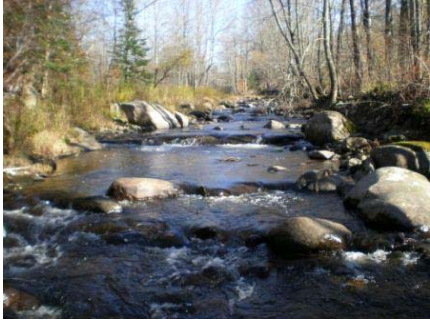


REACH NUMBER	METHOD	BENEFIT	DESCRIPTION	FEASIBILITY/ CONSTRAINTS	COST	LANDUSE CONVER- SION	PARTNERS
M06 	Protect River Corridor	Upstream of Constrained/ Altered Reach with existing FEH Hazards.	Reach M06 lies upstream of the constrained and altered reaches of Cuttingsville Village	Adoption of an FEH Zone will need to go through town planning.	Low	Potential restriction on land-use depending on easement language.	Town, RRPC, VTANR
	Berm Removal Site	Flood and sediment attenuation asset	Remove and/or relocate berm to allow some floodplain access and restore flow to a flood chute.	Cost of berm relocation and reforestation.	Med.	No additional structures in corridor	Landowners, RNRCD, ANR
	Restore Riparian Buffer	Improve shade, stability of river, habitat	Buffer has been removed along a good portion of right bank due to armoring along the road.	Very little room for reforestation	Low	Barren to forest	VTANR, RNRCD
M05-B 	Protect River Corridor	Inform Residents of FEH Hazards	This is an already highly settled area and residents should be made aware of Fluvial Erosion Hazards.	Adoption of an FEH Zone will need to go through town planning.	Low	Potential restriction on land-use depending on easement language.	Town, RRPC, VTANR
	Restore Riparian Buffer	Improve shade, stability of river, habitat	Buffer has been removed along a good portion reach.	Low	Bare to forest	VTANR, RNRCD	Improve shade, stability of river, habitat



REACH NUMBER	METHOD	BENEFIT	DESCRIPTION	FEASIBILITY/ CONSTRAINTS	COST	LANDUSE CONVER- SION	PARTNERS
M05-A 	Protect River Corridor	Sediment Attenuation Area (Conserve and Enhance)	This fairly undeveloped reach is already attenuating floodwaters and sediment. Long term river corridor protection would reduce future conflict and ensure these functions are served for future generations.	Railroad has R.O.W. in corridor. Otherwise no obvious restrictions.	Unk.	Remain forested undeveloped area.	Town, RRPC, VTANR
	Protect River Corridor	Reduce FEH at Alluvial Fan	Due to the significant slope change, this area is especially susceptible to sediment aggradation and planform adjustment.	Adoption of an FEH Zone will need to go through town planning.	Unk.	Potential restriction on land-use depending on easement language.	Town, RRPC, VTANR
M01-B 	Restore Riparian Buffer	Improve shade, stability of river, habitat	Short corner of field is lacking adequate buffer.	None.	Low	Bare to forest	VTANR, RNRCD, CREP
	Berm Removal Site	Improve floodplain access by removing bermed material.	Large berm on right bank may be removed or relocated.	Berm looks to be protecting farmland. Removing berm may affect crops.	Med.	Remains forested and agricultural land.	VTANR



REACH NUMBER	METHOD	BENEFIT	DESCRIPTION	FEASIBILITY/ CONSTRAINTS	COST	LANDUSE CONVERSION	PARTNERS
M01-A 	Protect River Corridor	Reduce FEH at Alluvial Fan	Due to the significant slope change, this area is especially susceptible to sediment aggradation and planform adjustment.	Landowner is interested in buffer protection.	Unk.	Remains forested and agricultural land.	VTANR, CREP, RNRCD
	Restore Riparian Buffer	Improve shade, stability of river, habitat	Buffer in area to protect stream as well as crops.	None.	Low	Bare to forest	VTANR, RNRCD, CREP
T2.01-B 	Protect River Corridor	Upstream of Constrained/ Altered Reach with existing FEH Hazards	Reach T2.01-B lies upstream of the constrained and altered reaches of Cuttingsville Village. This is an already highly settled area and residents should be made aware of Fluvial Erosion Hazards.	Adoption of an FEH Zone will need to go through town planning.	Low	Potential restriction on land-use depending on easement language.	Town, RRPC, VTANR




REACH NUMBER	METHOD	BENEFIT	DESCRIPTION	FEASIBILITY/ CONSTRAINTS	COST	LANDUSE CONVER- SION	PARTNERS
T2.01-A 	Protect River Corridor	Reduce FEH Hazards	This is a highly sensitive reach with a major departure from equilibrium conditions.	Adoption of an FEH Zone will need to go through town planning.	Low	Potential restriction on land-use depending on easement language.	Town, RRPC, VTANR
	Restore Riparian Buffer	Improve shade, stability of river, habitat	Buffer in area to protect stream as well as crops.	None.	Low	Bare to forest	VTANR, RNRCD, CREP



Table 8: Mill River High Priority Sites for Restoration and Protection - Updated 12/13/09 (BCE and RRD)

Reach	Condition and Channel Evolution Stage	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
M01-A	Fair, Stage IV	Confluence with Otter Creek, active Agriculture on right bank and pasture in between channels.	Conserve and Protect River Corridor and existing buffer, manage braided channel.	High priority	Flood and sediment attenuation asset for Otter Creek and Lake Champlain	Cost of river corridor easements and possible Phase 3 assessment.	Potential to keep agricultural use with BMPs	Landowners, RNRCD, ANR, VRC, CREP, WHIP
M06	Fair, Stage III	Agricultural field	Protect River Corridor to provide attenuation area	High priority (important location in watershed)	Flood and sediment attenuation asset	Cost of river corridor easement acquisition, WHIP	Land use conversion may be minimal	ANR, VRC, RNRCD, WHIP
M11-B	Fair, STD C to B, Stage III	Few lateral constraints in reach; upstream of E. Wallingford Village and long stretch that has been significantly altered by floodplain encroachment Soils maps show alluvial soils so maybe historic deposition area. Some gravel mining currently occurring indicated current deposition.	Protect River Corridor, Examine restore incised reach. Restore riparian buffer.	High priority –above reach that is significantly altered by floodplain encroachment. Land use is currently agricultural.	Floodwater and sediment attenuation area upstream of reach with significant floodplain encroachment	Cost of river corridor easements; possible cost of geomorphic project; cost of trees and shrubs, CREP, WHIP	Loss of agricultural land.	Landowners, CREP, RNRCD, ANR, VRC
T2.01-A	Fair, STD C to F, Stage II	Located in the Village of East Wallingford and constrained by a road on one side, but only agricultural land on the other.	Enroll in CREP or WHIP, possible floodplain redevelopment.	High priority	Improved sediment and floodwater attenuation above the Village.	Would be a large cost to redevelop floodplain.	Agricultural land to forest.	Landowners, RNRCD, ANR, CREP, WHIP



Reach	Condition and Channel Evolution Stage	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
M07	Fair, STD C to F, Stage III	Existing houses in River Corridor, one currently for sale.	Possible berm removal project, land conservation to public land.	High priority	Improve sediment transport and floodplain access upstream of Cuttingsville.	Cost of property acquisition and berm removal.	Private to public.	Landowners, ANR, RNRCD, FEMA, WHIP
M11-A	Fair, STD C to F, Stage II	Located in the Village of East Wallingford and constrained by buildings and roads and berm (keeping it in stage II)	Replace degraded bridge and pier that is causing sediment transport disruption and relocate berm on right bank	High priority (Bridge scheduled for replacement?)	Increase sediment transport through Village, reduce flood hazard in village, remove split flow in channel, create some floodplain in vital area upstream of bridge.	Large cost to replace bridge	Trees that have grown on berm would have to be removed.	Landowners, RNRCD, ANR, VTRANS
M14	Fair, STD C to B, Stage III	Located upstream of the Village of East Wallingford. Some limitation by the Valley wall and a road on the right side, agricultural land and limited development on the left bank.	Enroll in CREP or WHIP, possible floodplain redevelopment.	Med priority	Improved sediment and floodwater attenuation above the Village.	Would be a large cost to redevelop floodplain.	Agricultural land to forest.	Landowners, RNRCD, ANR, CREP, WHIP
M15	Fair, STD C to B, Stage III	Located upstream of the Village of East Wallingford. Forest on one right bank, agricultural land on the left bank.	Enroll in CREP or WHIP, possible floodplain redevelopment.	Med priority	Improved sediment and floodwater attenuation above the Village.	Would be a large cost to redevelop floodplain.	Agricultural land to forest.	Landowners, RNRCD, ANR, CREP, WHIP
M09	Fair, STD C to B, Stage III	Riparian banks influenced by agricultural practices; historically straightened	Relocate berm back from stream so that road is still protected but that stream has some floodplain access.	Low priority	Flood and sediment attenuation asset; habitat improvement	Cost of river corridor easement acquisition, engineering design and construction.	Young forest would have to be replanted. Possible conversion to public or conserved land.	CREP, ANR, VRC, RNRCD



Reach	Condition and Channel Evolution Stage	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Land Use Conversion	Potential Partners
M11-A	Fair, Stage II	Railroad bridge with road and river underneath causing channel constriction.	Alternatives Analysis for solving sediment transport and scour issues caused by constriction.	Low priority	Reduce sediment deposition and erosion caused by channel constriction.	Alternatives Analysis, sediment and hydraulic analysis, meetings with landowners	Dependent upon alternative selected	Landowners, RNRCD, ANR, Railroad
M06	Fair, Stage III	Private residences	Remove and/or relocate berm to allow some floodplain access and restore flow to a flood chute.	Low priority	Flood and sediment attenuation asset	Cost of berm relocation and reforestation.	No additional structures in corridor	Landowners, RNRCD, ANR, VRC
M06	Fair, Stage III	Public buildings and a parking lot.	Remove and/or relocate berm to allow some floodplain access.	Low priority – would allow some flood relief above Cuttingsville Village.	Improved sediment transport and geomorphic stability	Cost of design, relocation of berm, reforestation.	No additional structures in corridor	Town of Shrewsbury, ANR, Rutland NRCD
M10	Fair, STD C to B, Stage III	Private landowners property	Relocate berm back away from top of bank in order to allow some flood access, yet still protect structures. Stabilize mass failure.	Low Priority	Possibly reduce mass failure landslide on opposite bank.	Cost of berm relocation and trees and shrubs	None. Remains private property.	Property owner, ANR, RNRCD



7.4 Resources and Contacts for River Restoration and Management

Stream Alteration Permits, River Corridor Easements:

Vermont Department of Environmental Conservation
450 Asa Bloomer State Office Building
88 Merchants Row
Rutland, Vermont 05701-5903
Phone: 802-786-2501
Fax: 802.786.5915

Tree planting, Land conservation Assistance:

Rutland Natural Resources Conservation District
Nanci McGuire, District Manager
170 South Main Street
Rutland, VT 05701
phone: 802-775-7192 ext. 17
fax: 802-773-4177
email: nanci.mcguire@vt.nacdnet.net

Wetland restoration:

Sally Eugair, Soil Conservation Tech, USDA NRCS
170 South Main Street
Rutland, Vermont 05701
Phone: 1-802-775-7192 Ext.16
Fax: 1-802-773-4177

Assistance with Planning and Zoning:

Rutland Regional Planning Commission
P.O. Box 965
67 Merchants Row
Rutland, Vermont 05702
Phone: 802.775.0871
Fax: 802.775.1766

For information on Basin Planning and Water Quality Monitoring Projects in the Otter Creek Watershed visit:

http://www.vacd.org/rcd/district_maps.html

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9.0 GLOSSARY

Adapted from:

Glossary of Stream Restoration Terms

by Craig Fischenich.. February 2000

USAE Research and Development Center,
Environmental Laboratory, 3909 Halls Ferry
Rd., Vicksburg, MS 39180

TERMS

Adjustment process --a type of change, that is underway due to natural causes or human activity that has, or will, result in a change to the valley, floodplain, and/or channel condition (e.g., vertical, lateral, or channel plan form adjustment processes)

Aggradation -- A progressive buildup or raising of the channel bed and floodplain due to sediment deposition. The geologic process by which streambeds are raised in elevation and floodplains are formed. Aggradation indicates that stream discharge and/or bed-load characteristics are changing. Opposite of degradation.

Alluvial -- Deposited by running water.

Alluvium -- A general term for detrital deposits made by streams on riverbeds, floodplains, and alluvial fans; esp. a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include subaqueous sediments of seas or lakes.

Aquatic ecosystem -- Any body of water, such as a stream, lake, or estuary, and all organisms and nonliving components within it, functioning as a natural system.

Armoring -- A natural process where an erosion-resistant layer of relatively large particles is established on the surface of the streambed through removal of finer particles by stream flow. A properly armored streambed generally resists movement of bed material at discharges up to approximately 3/4 bank-full depth.

Avulsion -- A change in channel course that occurs when a stream suddenly breaks through its banks, typically bisecting an overextended meander arc.

Bank stability -- The ability of a streambank to counteract erosion or gravity forces.

Bankfull channel depth -- The maximum depth of a channel within a riffle segment when flowing at a bank-full discharge.

Bankfull channel width -- The top surface width of a stream channel when flowing at a bank-full discharge.



Bankfull discharge -- The stream discharge corresponding to the water stage that first overtops the natural banks. This flow occurs, on average, about once every 1 to 2 years.

Bankfull width -- The width of a river or stream channel between the highest banks on either side of a stream.

Bar -- An accumulation of alluvium (usually gravel or sand) caused by a decrease in sediment transport capacity on the inside of meander bends or in the center of an overwide channel.

Bed load -- Sediment moving on or near the streambed and transported by jumping, rolling, or sliding on the bed layer of a stream. See also suspended load.

Bed material -- The sediment mixture that a streambed is composed of.

Bed slope -- The inclination of the channel bottom, measured as the elevation drop per unit length of channel.

Berms -- mounds of dirt, earth, gravel, or other fill built parallel to the stream banks designed to keep flood flows from entering the adjacent floodplain.

Biota -- All living organisms of a region, as in a stream or other body of water.

Boulder -- A large substrate particle that is larger than cobble, 256 mm in diameter.

Braided channel -- A stream characterized by flow within several channels, which successively meet and divide. Braiding often occurs when sediment loading is too large to be carried by a single channel.

Buffer strip -- A barrier of permanent vegetation, either forest or other vegetation, between waterways and land uses such as agriculture or urban development, designed to intercept and filter out pollution before it reaches the surface water resource.

Canopy -- A layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand. Leaves, branches and vegetation that are above ground and/or water that provide shade and cover for fish and wildlife.

Channel -- An area that contains continuously or periodically flowing water that is confined by banks and a streambed.

Channelization -- The process of changing (usually straightening) the natural path of a waterway.

Clay -- Substrate particles that are smaller than silt and generally less than 0.003 mm in diameter.

Cobble -- Substrate particles that are smaller than boulders and larger than gravels, and are generally 64-256 mm in diameter. Can be further classified as small and large cobble.

Confluence -- (1) The act of flowing together; the meeting or junction of two or more streams; also, the place where these streams meet. (2) The stream or body of water formed by the junction of two or more streams; a combined flood.

Cover -- "cover" is the general term used to describe any structure that provides refugia for fish, reptiles or amphibians. These animals seek cover to hide from predators, to avoid warm water temperatures, and to rest, by avoiding higher velocity water. These animals come in all sizes, so even cobbles on the stream bottom that are not sedimented in with fine sands and silt can serve as cover for small fish and salamanders. Larger fish and reptiles often use large boulders, undercut banks, submerged logs, and snags for cover.

Culvert -- A buried pipe that allows flows to pass under a road.

Degradation -- (1) A progressive lowering of the channel bed due to scour. Degradation is an indicator that the stream's discharge and/or sediment load is changing. The opposite of aggradation. (2) A decrease in value for a designated use.

Ditch -- A long narrow trench or furrow dug in the ground, as for irrigation, drainage, or a boundary line.

Drainage area -- The total surface area upstream of a point on a stream that drains toward that point. Not to be confused with watershed. The drainage area may include one or more watersheds.

Ecology -- The study of the interrelationships of living organisms to one another and to their surroundings.

Ecosystem -- Recognizable, relatively homogeneous units, including the organisms they contain, their environment, and all the interactions among them.

Embankment -- An artificial deposit of material that is raised above the natural surface of the land and used to contain, divert, or store water, support roads or railways, or for other similar purposes.

Embeddedness -- is a measure of the amount of surface area of cobbles, boulders, snags and other stream bottom structures that is covered with sand and silt. An embedded streambed may be packed hard with sand and silt such that rocks in the stream bottom are difficult or impossible to pick up. The spaces between the rocks are filled with fine sediments, leaving little room for fish, amphibians, and bugs to use



the structures for cover, resting, spawning, and feeding. A streambed that is **not** embedded has loose rocks that are easily removed from the stream bottom, and may even “roll” on one another when you walk on them.

Entrenchment ratio -- The width of the floodprone area divided by the bankfull width.

Erosion -- Wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical, chemical, or biological forces.

Floodplain -- Land built of sediment that is regularly covered with water as a result of the flooding of a nearby stream.

Floodplain Function -- Flood water access of floodplain which effects the velocity, depth, and slope (stream power) of the flood flow thereby influencing the sediment transport characteristics of the flood (i.e., loss of floodplain access and function may lead to higher stream power and erosion during flood).

Flow -- The amount of water passing a particular point in a stream or river, usually expressed in cubic feet per second (cfs).

Fluvial -- Migrating between main rivers and tributaries. Of or pertaining to streams or rivers.

Ford -- A shallow place in a body of water, such as a river, where one can cross by walking or riding on an animal or in a vehicle.

Geographic information system (GIS) -- A computer system capable of storing and manipulating spatial data.

Geomorphology -- A branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place due to erosion of the primary elements and the buildup of erosional debris.

Gradient -- Vertical drop per unit of horizontal distance.

Gravel -- An unconsolidated natural accumulation of rounded rock fragments, mostly of particles larger than sand (diameter greater than 2 mm), such as boulders, cobbles, pebbles, granules, or any combination of these.

Habitat -- The local environment in which organisms normally live and grow.

Headwater -- Referring to the source of a stream or river.

Hydrologic balance -- An accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time.

Hydrology -- The scientific study of the water of the earth, its occurrence, circulation and distribution, its chemical and physical properties, and its interaction with its environment, including its relationship to living things.

Incised river -- A river that erodes its channel by the process of degradation to a lower base level than existed previously or is consistent with the current hydrology.

Incision ratio -- The low bank height divided by the bankfull maximum depth.

Infiltration (soil) -- The movement of water through the soil surface into the soil.

Instream cover -- The layers of vegetation, like trees, shrubs, and overhanging vegetation, that are in the stream or immediately adjacent to the wetted channel.

Islands -- mid-channel bars that are above the average water level and have established woody vegetation.

Large woody debris (LWD) -- Pieces of wood at least 6 ft. long and 1 ft. in diameter (at the large end) contained, at least partially, within the bankfull channel.

Mainstem -- The principal channel of a drainage system into which other smaller streams or rivers flow.

Meander -- The winding of a stream channel, usually in an erodible alluvial valley. A series of sine-generated curves characterized by curved flow and alternating banks and shoals.

Mid-channel Bars -- bars located in the channel away from the banks, generally found in areas where the channel runs straight. Mid-channel bars are caused by recent channel instability and are unvegetated.

Outfall -- The mouth or outlet of a river, stream, lake, drain or sewer.

Point bar -- The convex side of a meander bend that is built up due to sediment deposition.

Pool -- A reach of stream that is characterized by deep, low-velocity water and a smooth surface.

Reach -- A section of stream having relatively uniform physical attributes, such as valley confinement, valley slope, sinuosity, dominant bed material, and bed form, as determined in the Phase 1 Assessment.

Restoration -- The return of an ecosystem to a close approximation of its condition prior to disturbance.



Riffle -- A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

Riffle/step frequency -- ratio of the distance between riffles to the stream width.

Riparian area -- An area of land and vegetation adjacent to a stream (or any other freshwater aquatic ecosystem) that has a direct effect on the stream. This includes woodlands, vegetation, and floodplains.

Riparian buffer is the width of naturally vegetated land adjacent to the stream between the top of the bank (or top of slope, depending on site characteristics) and the edge of other land uses. A buffer is largely undisturbed and consists of the trees, shrubs, groundcover plants, duff layer, and naturally uneven ground surface. The buffer serves to protect the water body from the impacts of adjacent land uses.

Riparian corridor includes lands defined by the lateral extent of a stream's meanders necessary to maintain a stable stream dimension, pattern, profile, and sediment regime. For instance, in stable pool-riffle streams, riparian corridors may be as wide as 10-12 times the channel's bankfull width. In addition the riparian corridor typically corresponds to the land area surrounding and including the stream that supports (or could support if unimpacted) a distinct ecosystem, generally with abundant and diverse plant and animal communities (as compared with upland communities).

Riparian habitat -- The aquatic and terrestrial habitat adjacent to streams, lakes, and other freshwater aquatic ecosystems.

Riparian -- Located on the banks of a stream or other body of freshwater.

Riparian vegetation -- The plants that grow adjacent to a wetland area such as a river, stream, reservoir, pond, spring, marsh, bog, meadow, etc., and that rely upon the hydrology of the associated water body.

Riprap -- Rock or other material with a specific mixture of sizes referred to as a "gradation," used to stabilize streambanks or riverbanks from erosion or to create habitat features in a stream.

River channels -- Large natural or artificial open streams that continuously or periodically contain moving water, or which form a connection between two bodies of water.

River reach -- Any defined length of a river.

Roads - Transportation infrastructure. Includes private, town, state roads, and roads that are dirt, gravel, or paved.

Runoff -- Water that flows over the ground and reaches a stream as a result of rainfall or snowmelt.

Scour -- The erosive action of running water in streams, which excavates and carries away material from the bed and banks. Scour may occur in both earth and solid rock material and can be classed as general, contraction, or local scour.

Sediment -- Soil or mineral material transported by water or wind and deposited in streams or other bodies of water.

Sedimentation -- (1) The combined processes of soil erosion, entrainment, transport, deposition, and consolidation. (2) Deposition of sediment.

Segment: A relatively homogenous section of stream contained within a reach that has the same reference stream characteristics but is distinct from other segments in the reach in one or more of the following parameters: degree of floodplain encroachment, presence/absence of grade controls, bankfull channel dimensions (W/D ratio, entrenchment), channel sinuosity and slope, riparian buffer and corridor conditions, abundance of springs/seeps/adjacent wetlands/stormwater inputs, and degree of channel alterations.

Sensitivity --of the valley, floodplain, and/or channel condition to change due to natural causes and/or anticipated human activity.

Silt -- Substrate particles smaller than sand and larger than clay (3 to 60 mm).

Sinuosity -- The ratio of channel length to direct down-valley distance. Also may be expressed as the ratio of down-valley slope to channel slope.

Slope -- The ratio of the change in elevation over distance.

Stable channel -- A stream channel with the right balance of slope, planform, and cross section to transport both the water and sediment load without net long-term bed or bank sediment deposition or erosion throughout the stream segment.

Straightening -- the removal of meander bends, often done in towns and along roadways, railroads, and agricultural fields.



Stream banks are features that define the channel sides and contain stream flow within the channel; this is the portion of the channel bank that is between the toe of the bank slope and the bankfull elevation. The banks are distinct from the streambed, which is normally wetted and provides a substrate that supports aquatic organisms. The top of bank is the point where an abrupt change in slope is evident, and where the stream is generally able to overflow the banks and enter the adjacent floodplain during flows at or exceeding the average annual high water.

Stream channel -- A long narrow depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.

Stream condition -- Given the land use, channel and floodplain modifications documented at the assessment sites, the current degree of change in the channel and floodplain from the reference condition for parameters such as dimension, pattern, profile, sediment regime, and vegetation.

Stream morphology -- The form and structure of streams.

Stream reach -- An individual segment of stream that has beginning and ending points defined by identifiable features such as where a tributary confluence changes the channel character or order.

Stream type -- Gives the overall physical characteristics of the channel and helps predict the reference or stable condition of the reach.

Streambank armoring -- The installation of concrete walls, gabions, stone riprap, and other large erosion resistant material along stream banks.

Streambank erosion -- The removal of soil from streambanks by flowing water.

Streambank stabilization -- The lining of streambanks with riprap, matting, etc., or other measures intended to control erosion.

Streambed -- (1) The unvegetated portion of a channel boundary below the baseflow level. (2) The channel through which a natural stream of water runs or used to run, as a dry streambed.

Substrate -- (1) The composition of a streambed, including either mineral or organic materials. (2) Material that forms an attachment medium for organisms.

Suspended sediment -- Sediment suspended in a fluid by the upward components of turbulent currents, moving ice, or wind.

Tributary -- A stream that flows into another stream, river, or lake.

Urban runoff -- Storm water from city streets and gutters that usually carries a great deal of litter and organic and bacterial wastes into the sewer systems and receiving waters.

Water quality -- A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Watershed -- An area of land whose total surface drainage flows to a single point in a stream.

Watershed management -- The analysis, protection, development, operation, or maintenance of the land, vegetation, and water resources of a drainage basin for the conservation of all its resources for the benefit of its residents.

Watershed restoration -- Improving current conditions of watersheds to restore degraded habitat and provide long-term protection to aquatic and riparian resources.

APPENDIX A

STRESSOR IDENTIFICATION MAPS



Mill River Watershed Hydrologic Alterations Map: Stormwater

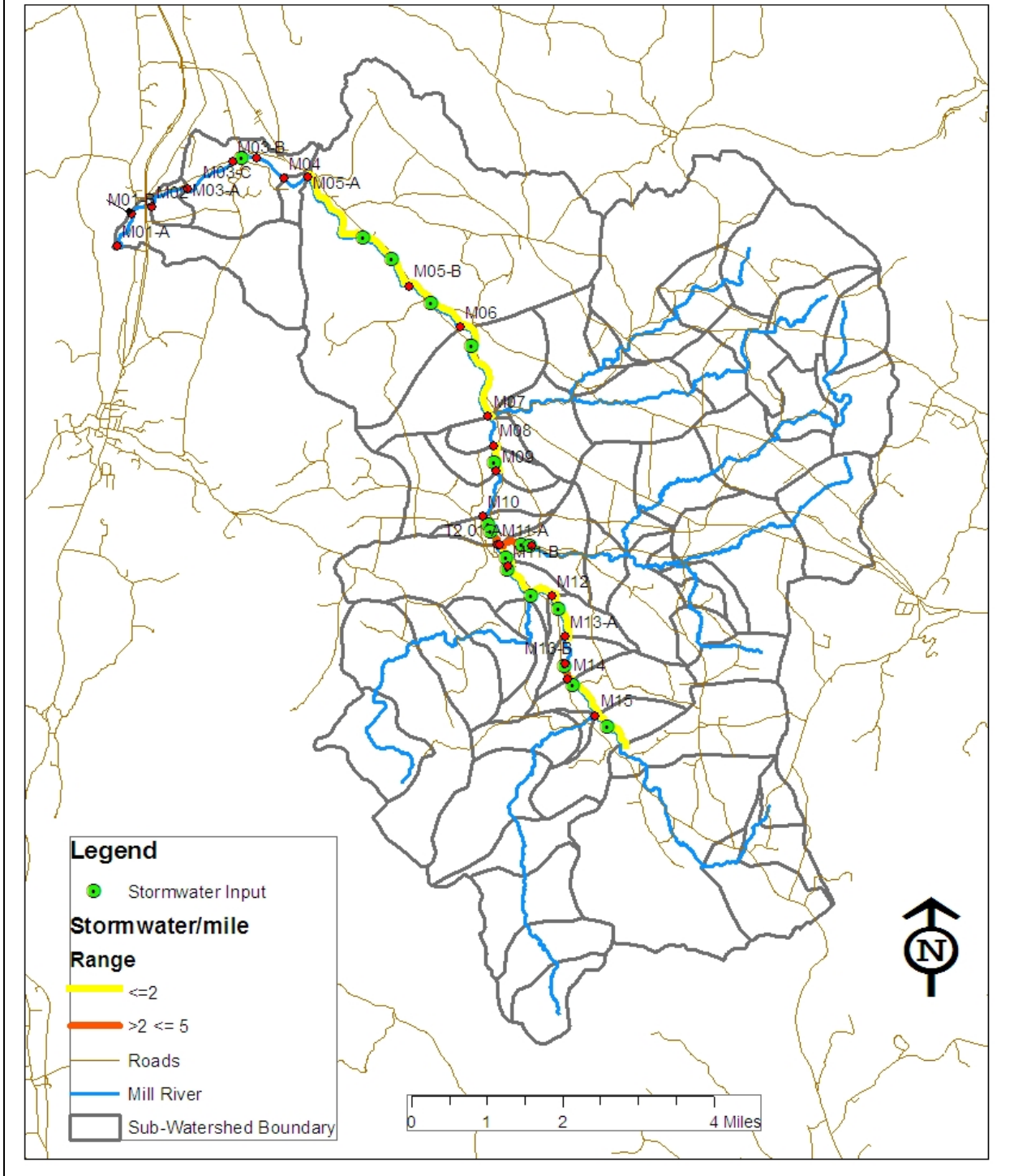


Figure 1. Hydrologic Alterations Map of the Mill River Watershed depicting Stormwater Inputs.



Mill River Watershed Hydrologic Alterations Map: Wetland Loss and Cropland Impact

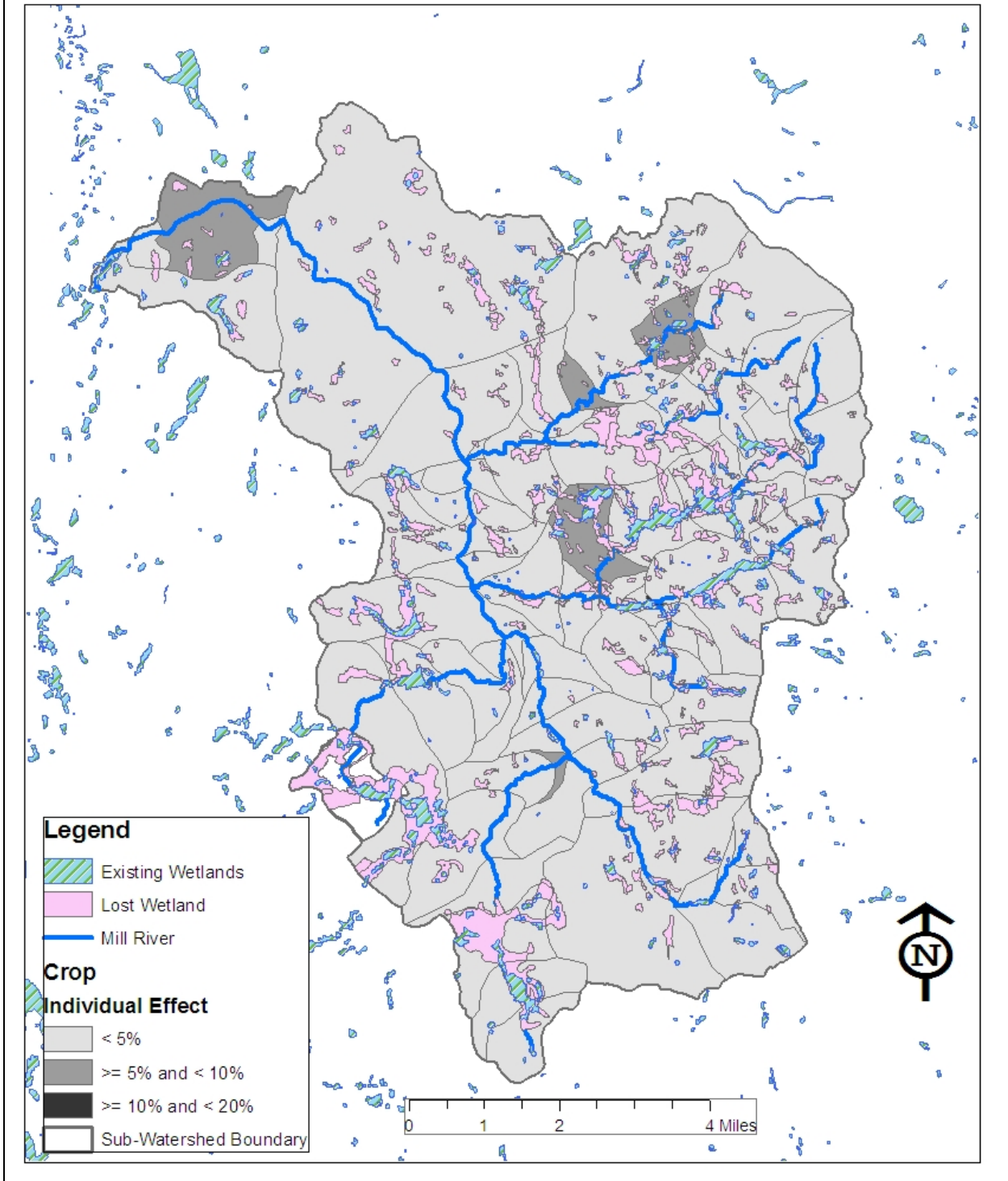


Figure 2: Wetland loss and the effect of cropland on the Mill River and its tributaries.



Mill River Watershed Sediment Load Alterations Map: Sediment Load Indicators Map

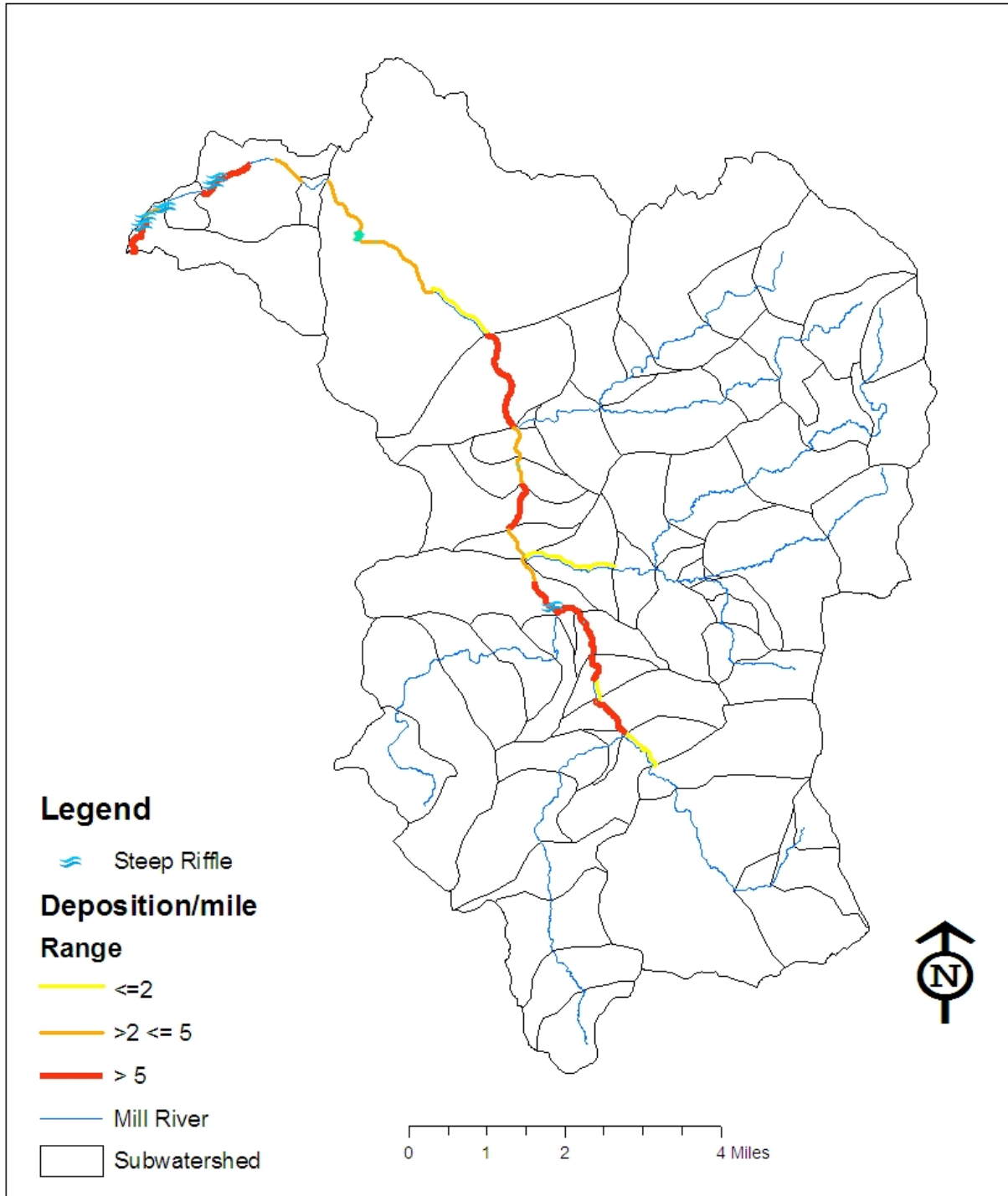


Figure 3: Indicators of excessive sediment loading in the Mill River.



Mill River Watershed Channel Slope Modifiers Map: Channel Slope Increases (Straightening)

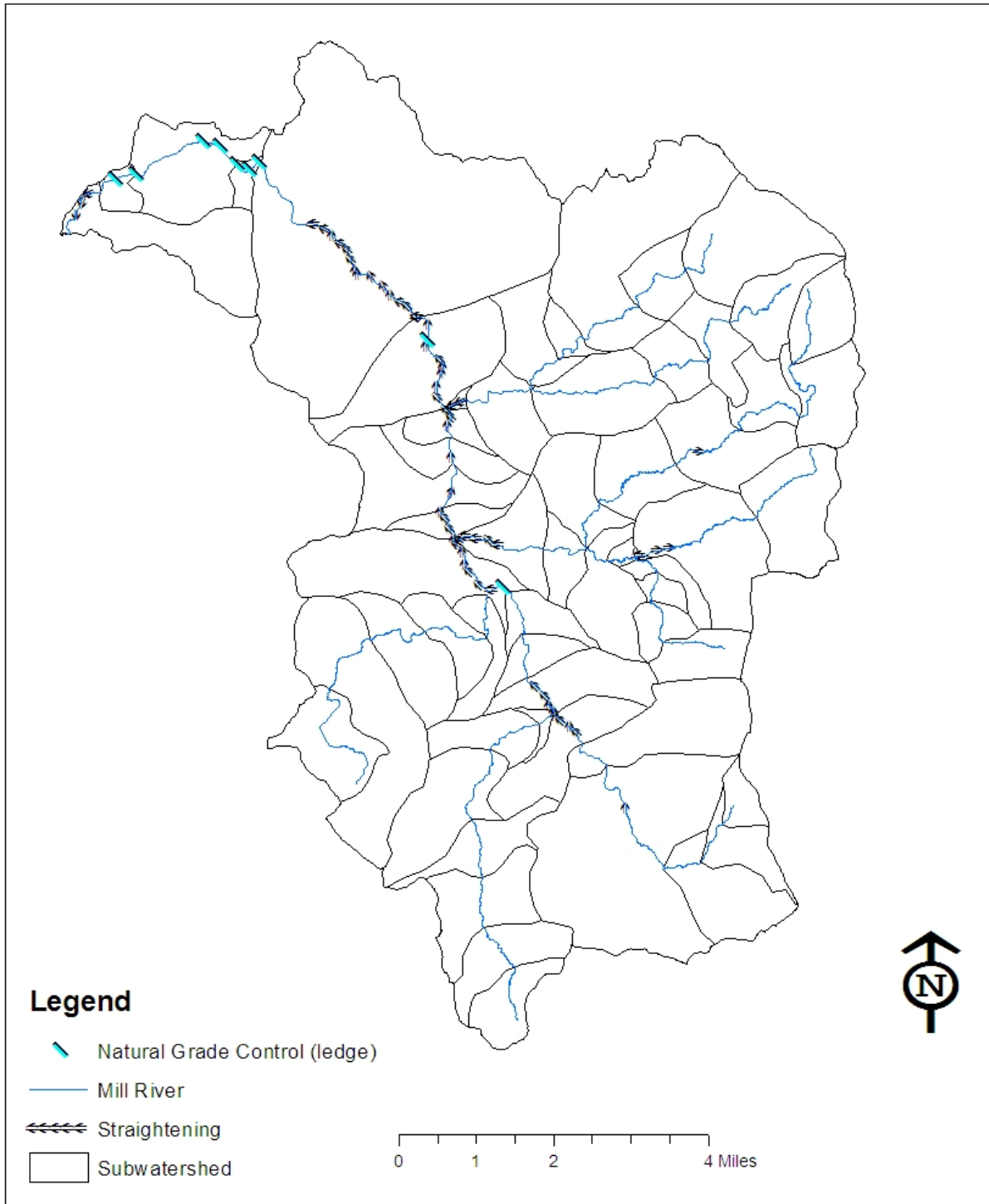


Figure 4: Channel straightening and grade control locations on the Mill River and its tributaries.



Mill River Watershed Channel Depth Modifiers Map: Increase in Channel Depth from Floodplain Encroachment

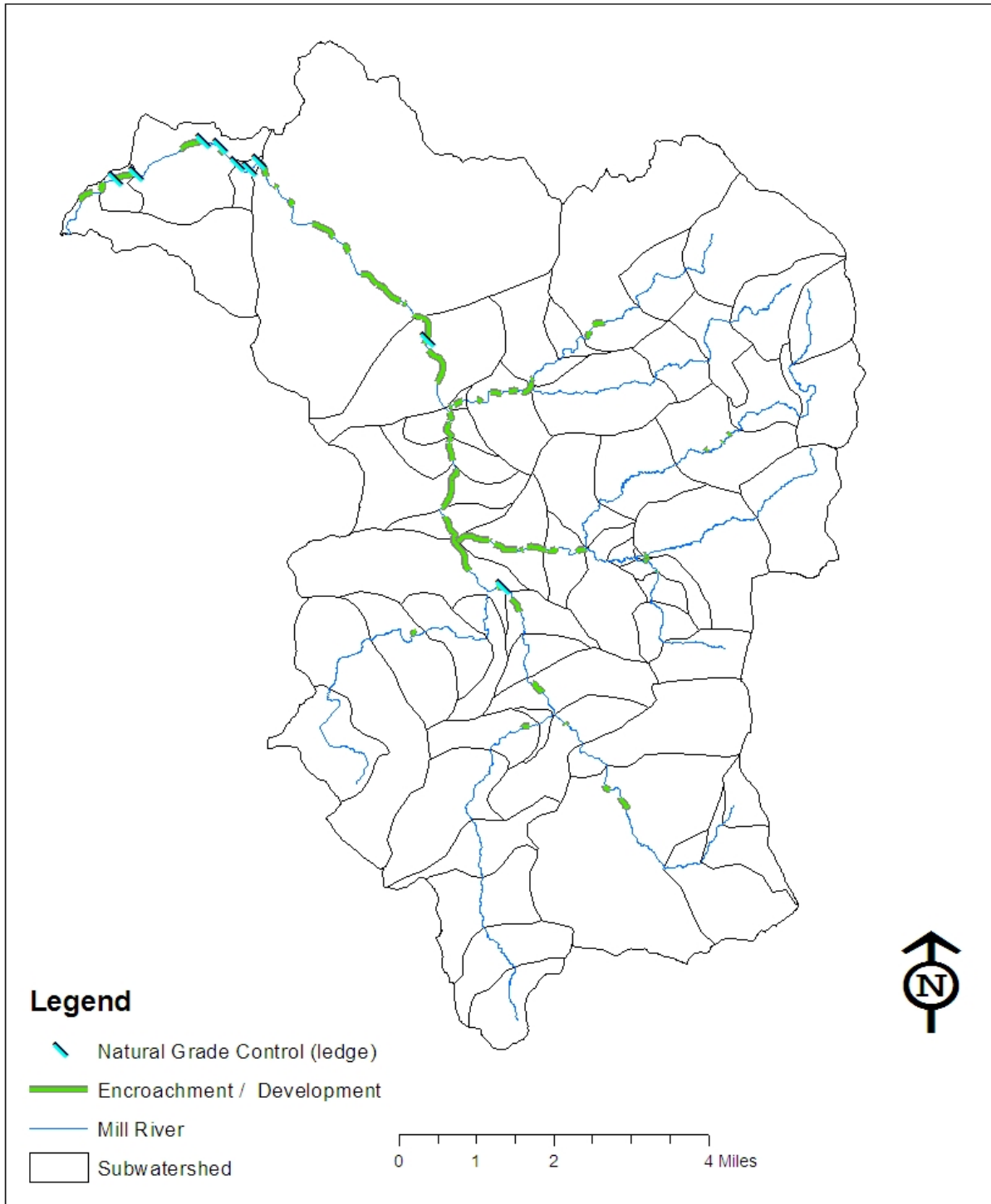


Figure 5: Increase in channel depth as a result of floodplain encroachment on the Mill River and its tributaries.



Mill River Boundary and Riparian Conditions Modifiers Map: Areas with Less than 25 Feet of Riparian Vegetation

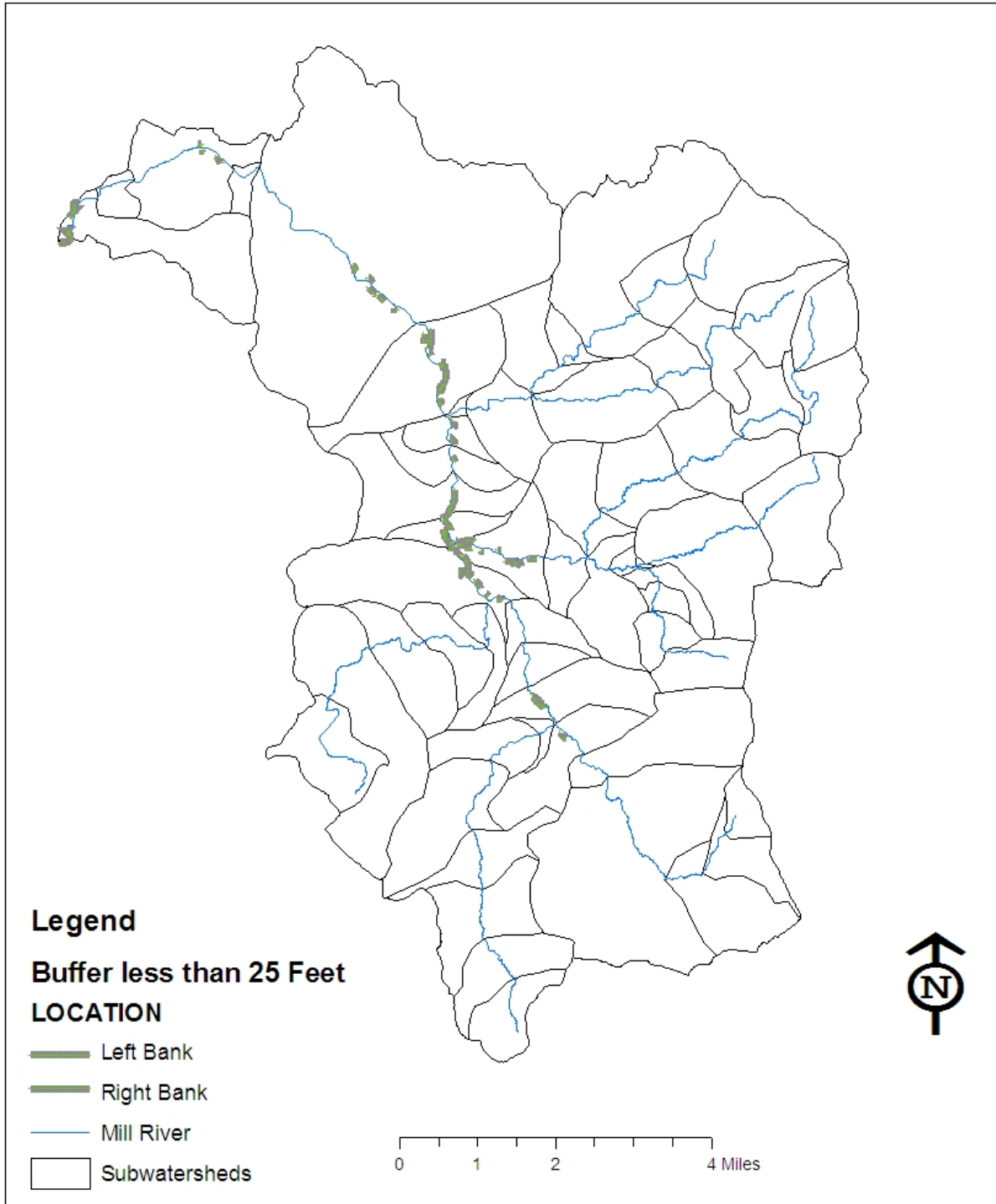


Figure 6: Loss of Riparian Buffer along the Mill River.

APPENDIX B

PHASE 2 REACH SUMMARIES



PHASE 2 RESULTS

The results of the Phase 2 study are discussed below by reach number. In addition, four overview maps (Figures 1, 11, 16, and 21) have been included to provide a reference for location as well as to display channel modifications such as straightening and berming, both of which have greatly affected the condition of the Mill River.

The most common adjustment processes observed in the Mill River are widening and planform migration as a result of historic degradation within the channel. Degradation is the term used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment. The planform is the channel shape as seen from the air. Planform change can be the result of a straightened course imposed on the river through different channel management activities, or a channel response to other adjustment processes such as aggradation and widening. Channel widening occurs when stream flows are contained in a channel as a result of degradation or floodplain encroachment or when sediments overwhelm the stream channel and the erosive energy is concentrated into both banks.

RIVER SECTION 1: MOUNT HOLLY TO EAST WALLINGFORD VILLAGE

The first section of river (illustrated in Figure 1) begins in Mount Holly and flows northerly towards East Wallingford Village. The valley alternates between very broad and narrow and land use changes from predominately agricultural and forested to commercial and residential in East Wallingford. Major significant impacts in this section include: removal of riparian vegetation, channel straightening, dredging, berming, channel armoring, and floodplain encroachment.



Mill River Watershed Phase 2 Geomorphic Assessment Reach Overview and Channel Alterations Map

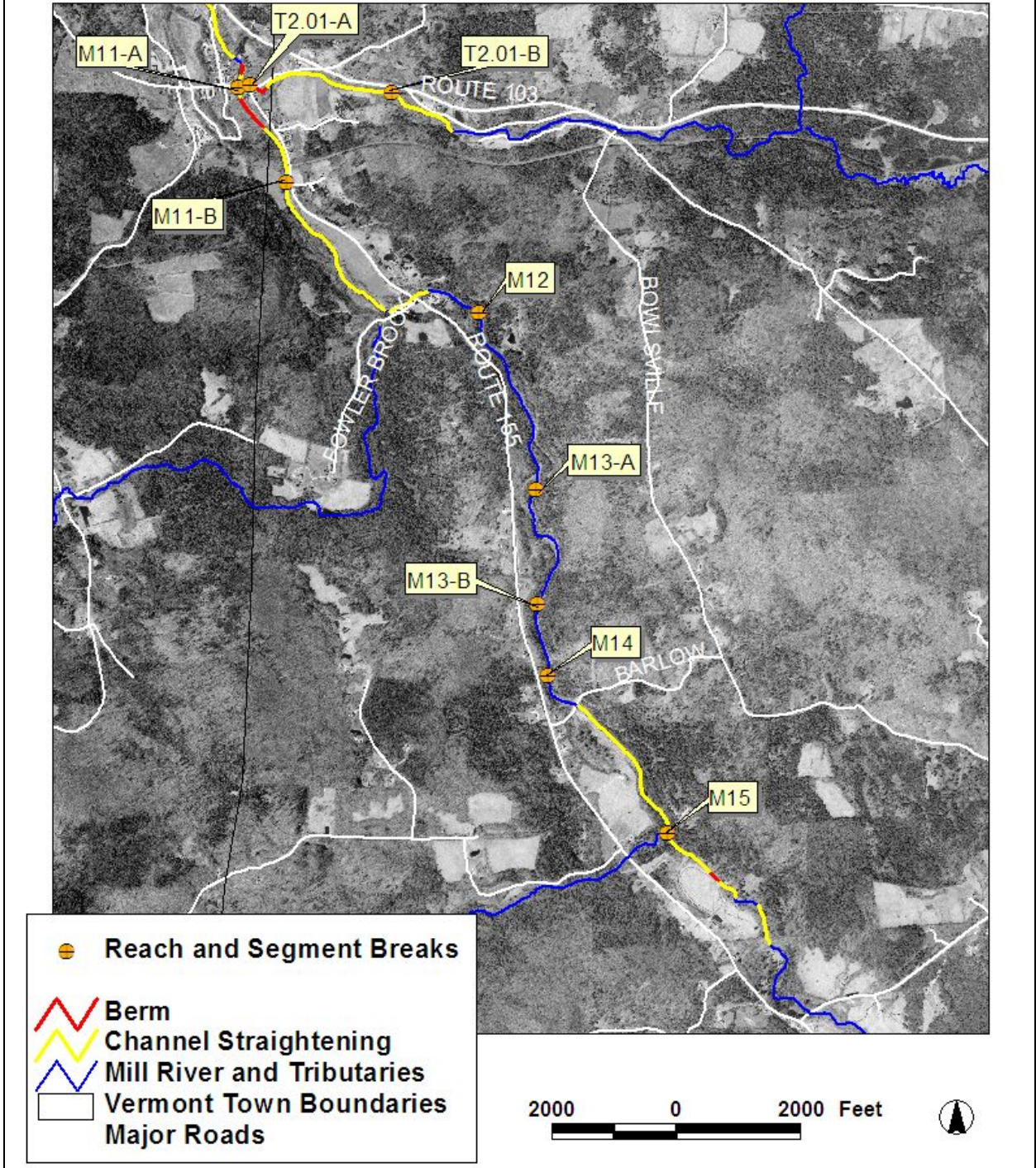


Figure 1: Overview of reaches M11 through M15 (including T2.01), and channel straightening and berming.



4.1 Reach M15

The most upstream reach of this Phase 2 study, M15 of the Mill River is located at approximately 1490 feet above sea level in a very broad valley in the town of Mount Holly. The land on the southwestern border of the stream is pasture land and it appears that the river through this reach has been straightened and pushed up against the right valley wall in order to make more room for agricultural activities. Deep down-cutting into the streambed material has occurred (incision ratio of 2) likely as a result of this straightening. A stream type departure from a reference C riffle-pool channel to a B type plane bed was recorded (Figure 2). This departure has significantly reduced the capacity of this reach to attenuate floodwater and sediment. Currently the reach is exhibiting only minor widening and planform adjustment. This is likely due to the large substrates in the channel. Continued lateral adjustment is expected to occur as the river works to redevelop floodplain in this reach.

Construction of a new bridge was observed. With the exception of this structure, the rest of the reach was undeveloped although as stated the left corridor is currently being used for pasture and hay. By reference this reach should be an area where floodwaters and sediment are able to be stored in the Mill River system. Drainage work in the fields indicates that much of the land may be class III wetland. A riparian buffer restoration project on the left bank may be appropriate as only a very narrow row of trees currently exists.



Figure 2. Reach M15 has been historically straightened. It is an incised channel with a planebed form that is currently undergoing minor channel widening and planform adjustment.

4.2 Reach M14

Reach M14 begins where Meadow Brook enters the Mill River in the town of Mount Holly. Similar to M15, this reach borders recently agricultural (some no longer in



production) land. The river through this reach appears to have been straightened (Figure 3) and pushed up against the right (northeast) valley wall. An old meander scar is visible on aerial photographs just upstream from the Barlow Road Bridge indicating a level of historic sinuosity has been lost. Deep incision was observed (measured ratio of 3). A stream type departure has ensued from a C-type channel to a B-type plane bed with a significantly reduced capacity to attenuate water and sediment due to the disconnection with the floodplain. Extensive widening and minor planform adjustments are occurring in the reach as the channel works to recover from the high level of incision.

Also of note in this reach, a large delta exists at the Meadow Brook confluence. The brook appears to be contributing coarse and fine sediment to the system as a result of tributary rejuvenation and possible other adjustments upstream. In regards to land use in the M14 corridor a single residence exists on the left bank. With much of the corridor still void of trees and undeveloped this reach may be suitable for an active geomorphic restoration project and/or buffer restoration efforts on the left bank.



Figure 3. M14 has been historically straightened and is now has a plane bed form. Widening and planform adjustment are actively occurring.

4.3 Reach M13

Mill River reach M13 begins below the Barlow Road Bridge in Mount Holly (off of Vermont Route 155) and continues downstream for 3399 feet. The reach was split into two segments by RRD due to a natural change in channel confinement related to the valley width. This change in channel confinement resulted in a change in reference stream type within the reach.



Segment B:

Reach M13-B is a short segment located where the valley wall of the Mill River narrows thereby creating a semi-confined channel that is a B3 planebed by reference (Figure 4). Some development has occurred along the top of the left valley wall, however, the development is well above the floodplain and is only mentioned as the landowners in this reach are in close proximity to the stream and may have an impact on its water quality. These houses are also located on top of a steep valley wall and may have some erosion hazard risks. Landowner education in this area to ensure that the forested buffer remains intact and stormwater and garbage is minimized from entering the channel would be beneficial in this segment.

In regards to the observed stream condition, the channel was found to be slightly incised. Some minor widening has occurred. Extreme adjustments are unlikely in this reach due to the stable tendencies of B3 planebed streams.

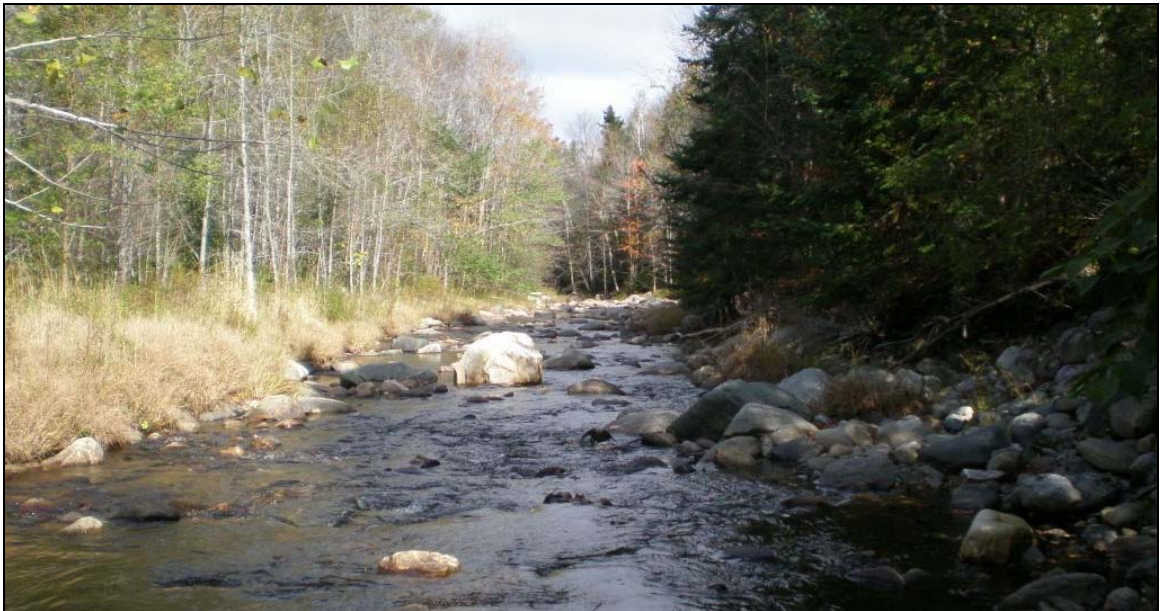


Figure 4. M13-B is a B3 planebed segment by reference.

Segment A:

Mill River segment M13-A is a short segment located in a broad valley. Historic channel incision has led to minor channel widening and major channel planform adjustments. Despite a high degree of incision the stream has remained a C-type channel dominated by gravel substrates (Figure 5). The river is adjusting laterally through several flood chutes and has stored a significant amount of gravel in a large point bar. The well forested buffer in this corridor is an asset for the river as are the floodchutes and wetlands that will store some water and sediment during a large runoff event.



Figure 5. M13-A is a C type channel that is undergoing planform adjustment and minor widening.

4.4 Reach M12

Mill River reach M12 begins upstream from Fowler Brook Road in the town of Mount Holly. This is a C channel that flows through a well forested corridor in a broad valley (Figure 6). Historic incision has led to a great degree of instability in the channel. There were numerous active flood chutes documented as well as new gravel bars indicating both planform adjustment and aggradation as the channel works to redevelop floodplain. Channel widening was also considered a major active adjustment process. This reach may be both a source and sink of sediment and flood waters and will become more of a resource for the watershed as the channel evolution processes continue to improve floodplain access.



Figure 6. M12 has incised historically. Major planform adjustment, widening, and minor aggradation were observed.



4.5 Reach M11

Mill River reach M11 begins just upstream from where Fowler Brook enters the mainstem and continues downstream to East Wallingford Village where another tributary (T2.01) enters from the east. M11 was divided into two segments for the Phase 2 assessment due to an observed change in the degree of corridor encroachment, bank armoring, buffer quality, and corridor land use. The segment break was near a railroad bridge crossing from which point downstream the channel is heavily impacted by straightening, streambank armoring, floodplain development, and fill.

Segment B:

Mill River segment M11-B captures an area where the valley walls open up and a tributary enters the Mill River from the west. In this segment, soils maps indicate that the parent material is alluvial suggesting the possibility that this area is an alluvial fan. There appears to have been a high degree of historic channel straightening that occurred in this reach, likely in order to increase the amount of agricultural land which dominates the right corridor. In addition active gravel extraction was observed to have recently occurred in the reach.

A high degree of channel incision has caused a departure from a C-type channel to a B plane bed (Figure 7). These channel alterations have caused a significant loss of sediment and floodwater attenuation in an important area upstream of East Wallingford and Cuttingsville Villages.



Figure 7. M11-B has been historically straightened. Currently undergoing major planform, widening, and aggradation adjustments.



Segment A:

Mill River segment M11-A is one of two reaches that run through the Village of East Wallingford. Due to the relative location of the village to the river, extensive channel straightening, armoring, and dredging have altered this channel, likely in response to past flood events. These alterations have transformed riffle-pool system in a broad valley into a F-type stream with a plane bed form lacking in habitat as well as floodwater and sediment storage capabilities. Vermont Route 155 and commercial and residential development have significantly encroached on the channel (Figure 8). The bridge at the downstream end of the reach appears to be a debris/ice jam potential hazard - it already has held enough sediment behind the middle pier for a fully vegetated mid-channel bar to form. In addition a railroad bridge crossing which funnels both a road and the river underneath appears to be limiting sediment transport. The upstream aggradation the bridge is causing may be increasing an erosion issue on pasture land on the left bank of M11-B. Opportunities to increase conveyance of water and sediment underneath these bridges may be appropriate projects to reduce fluvial erosion hazard in East Wallingford Village.

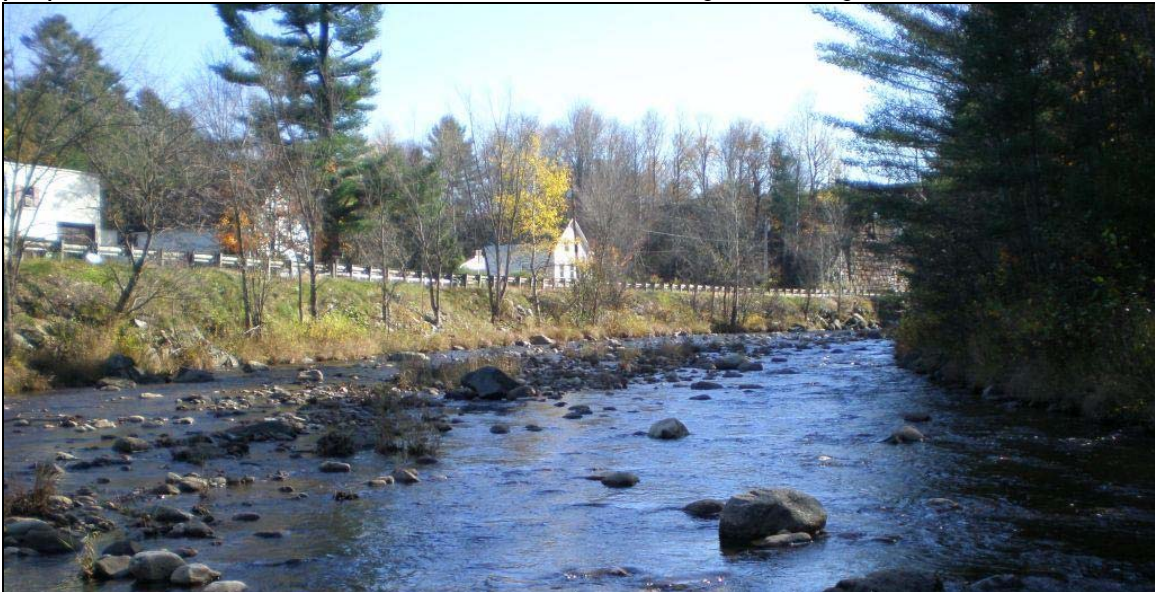


Figure 8. M11-A flows through East Wallingford Village and has a high degree of incision due to channel straightening and dredging.

4.5 Reach T2.01

Mill River watershed reach T2.01 is the downstream end of a large tributary to the Mill River. This tributary is unnamed on the 1984 USGS topography map. The reach studied for the Phase 2 Assessment begins at the Bowlsville Road Bridge and continues 6515 feet downstream to the confluence with the Mill River in East Wallingford Village. The reach was divided into two segments by RRD due to an extreme amount of channel straightening and bank armoring that was observed near the lower end of the reach.



Segment B:

Tributary T2.01-B begins at the Bowlsville Road Bridge and ends downstream near the west entrance to Millbrook Lane. The upper portion of this segment is in fair geomorphic condition. It has undergone major historic incision, however, is actively working to redevelop floodplain and has a fairly well developed riffle-pool bedform that looks to be providing good habitat with several deep pools. Active planform adjustment has led to the development of small gravel bars and a juvenile floodplain in some areas (Figure 9). Continued planform, widening, and aggradation adjustments are expected. Preventing further development of the floodplain of this reach will be an important step to ensure that floodwaters and sediment storage capacity is retained in this reach.

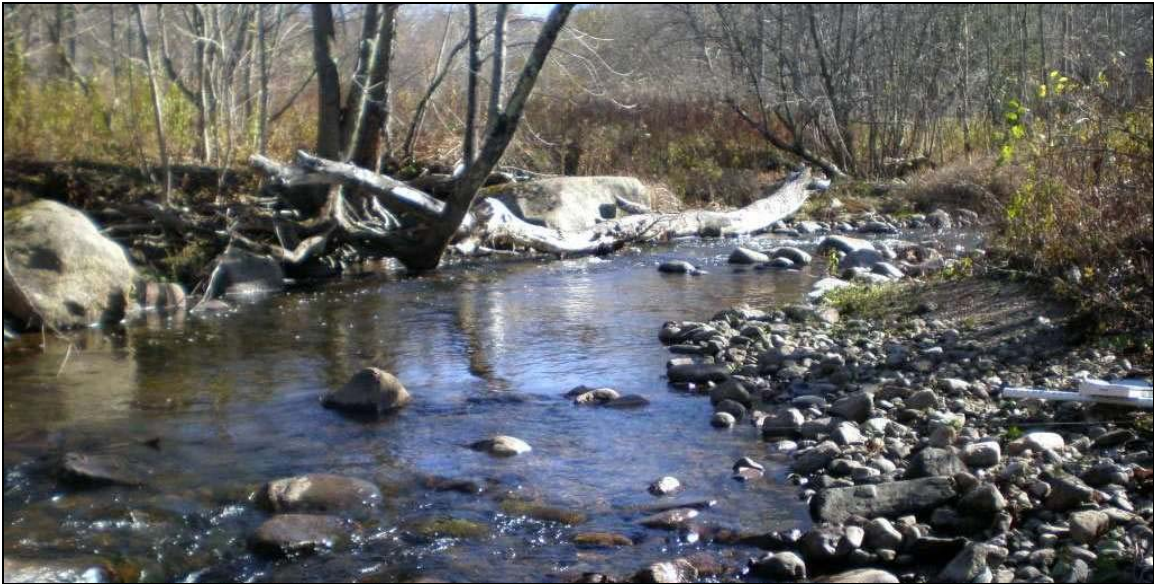


Figure 9. T2.01-B has historically incised, however is undergoing major planform adjustment as a new floodplain bench is developed.

Segment A

Tributary segment T2.01-A has seen extensive historic channel straightening and armoring (Figure 10). There is also evidence of dredging and windrowing just above the Route 140-East Bridge. The right side of the floodplain has been filled almost entirely by Routes 140 and 103 which create the top of the right bank. On the left side of the channel the riparian buffer has been cleared down to a thin strip of vegetation along the top of the bank. Agricultural land use dominates the left corridor while commercial and residential land use dominates the right corridor. Cross section analysis indicates that a stream type departure has occurred from a C-type channel to an F-type stream due to a high grade of incision.



Figure 10. T2.01-A has been historically straightened and is now has a plane bed system that is disconnected from its floodplain.

RIVER SECTION 2: EAST WALLINGFORD VILLAGE TO CUTTINGSVILLE

The second section of river (illustrated in Figure 11) begins below East Wallingford Village and continues downstream to Cuttingsville. The valley alternates between very broad and narrow and the land use changes from commercial and residential in East Wallingford to agricultural and then back to development in Cuttingsville. Major significant impacts in this section include removal of riparian vegetation, channel straightening and dredging, berming, channel armoring, and floodplain encroachment.



Mill River Watershed Phase 2 Geomorphic Assessment Reach Overview and Channel Alterations Map

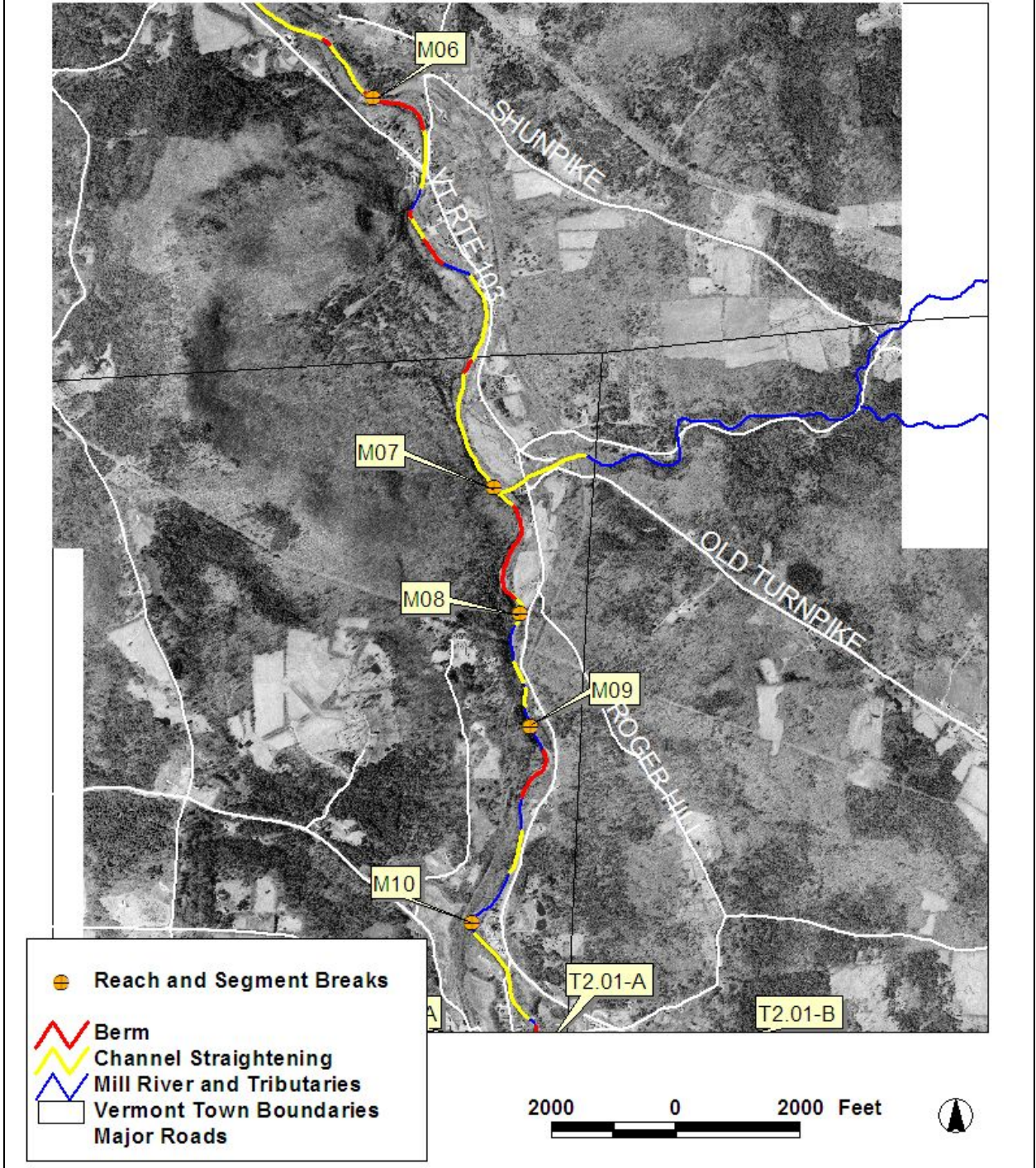


Figure 11: Overview of reaches M06 through M10 and channel straightening and berming.



4.6 Reach M10

Mill River reach M10 flows through East Wallingford Village. The reach begins just below the Route 140 Bridge at the confluence with tributary T2.01 and continues downstream for 2369 feet. This short reach has been highly managed in order to maintain its location and minimize flooding in the Village. RRD observed evidence of channel straightening and armoring (Figure 12). The high incision ratio has caused a stream type departure from a C-type channel which historically flowed through a forested broad valley to a B-type plane bed system that has a high degree of floodplain development. Due to the significant investment in infrastructure within this reach the Mill River is likely to be maintained near its current configuration. Deteriorating bridge conditions on Village Street may provide an opportunity for redesigning access to the Village and or at least allowing better sediment and water transport under the bridge (which is currently holding sediment in its mid-pier and may create debris jam and flooding under the right conditions).



Figure 12. M10 has been historically straightened. There is a high degree of bank armoring within the reach.

4.7 Reach M09

Although development pressure is not as significant as in the reach upstream, Mill River reach M09 has been impacted predominately by VT Route 103 which has changed the valley width from broad to narrow. In order to protect the roadway and a few structures located within the river corridor, extensive berming and channel armoring has occurred (Figure 13). Berming and straightening has increased the erosive forces in the channel leading to a high degree of incision (ratio of 1.8) and a stream type departure from a C riffle-pool channel to a B plane bed system. Adjusting to this incision, the stream has undergone extreme channel widening. Extensive channel management (riprap, dredging, straightening) has prevented the channel from developing new floodplain and storing sediment.



Figure 13. The valley width of M09 has been decreased due to encroachment from VT Route 103. The channel has undergone extreme widening.

4.8 Reach M08

Mill River reach M08 is a short reach in a semi-confined valley that has been further confined by Vermont Route 103. Despite a high degree of historic channel incision (Figure 14) the stream remains a C-type channel with access to floodplain during only the largest events. Although there is no stream type departure or bedform change (planebed by reference) the stream is nearly an F-type channel due to the high degree of incision. As a result of the incision the current sediment and floodwater storage capability of this reach has been significantly reduced.



Figure 14. M08 is a short reach that has limited floodplain access due to streambed degradation.



4.9 Reach M07

Mill River reach M07 is a very short reach that appears to have been straightened up against the left valley wall in order to increase cultivatable land. Significant berming has occurred on the right bank in order to prevent flooding (Figure 15). Incision and channel widening in response to these channel management activities have led to a stream type departure from a C channel to a F-type channel and loss of bedform from riffle-pool to plane bed system.



Figure 15. M07 has seen significant berming on the right bank causing a significant loss of floodplain access.

4.10 Reach M06

Mill River reach M06 runs directly through Cuttingsville Village with a great deal of human alteration, both historic and recent. Channel straightening, berming, dredging, armoring, and windrowing were all observed. Additionally much of the floodplain has been filled by development and roads (Figure 16) increasing stormwater inputs into the system. It appears that the stream may have been straightened and relocated up against the left valley wall through much of the reach. A high degree of incision (1.8 ratio) was observed with major channel widening and planform adjustments currently occurring. Although there was some evidence of juvenile floodplain creation most of the reach still lacks significant floodplain benches. Some opportunities for channel adjustment and floodplain reconnection still exist in this reach.



Figure 16. M06 flows through Cuttingsville and has been significantly impacted by channel straightening, armoring, berming, and floodplain development.

RIVER SECTION 3: CUTTINGSVILLE TO THE UPPER CLARENDON GORGE

The third major section of river (illustrated in Figure 17) begins just downstream of Cuttingsville Village. From here down to the upper Clarendon Gorge, the Mill River flows through a broad valley. Major significant impacts in this section include removal of riparian vegetation, channel straightening and dredging, corridor encroachment and an undersized bridge.



Mill River Watershed Phase 2 Geomorphic Assessment Reach Overview and Channel Alterations Map

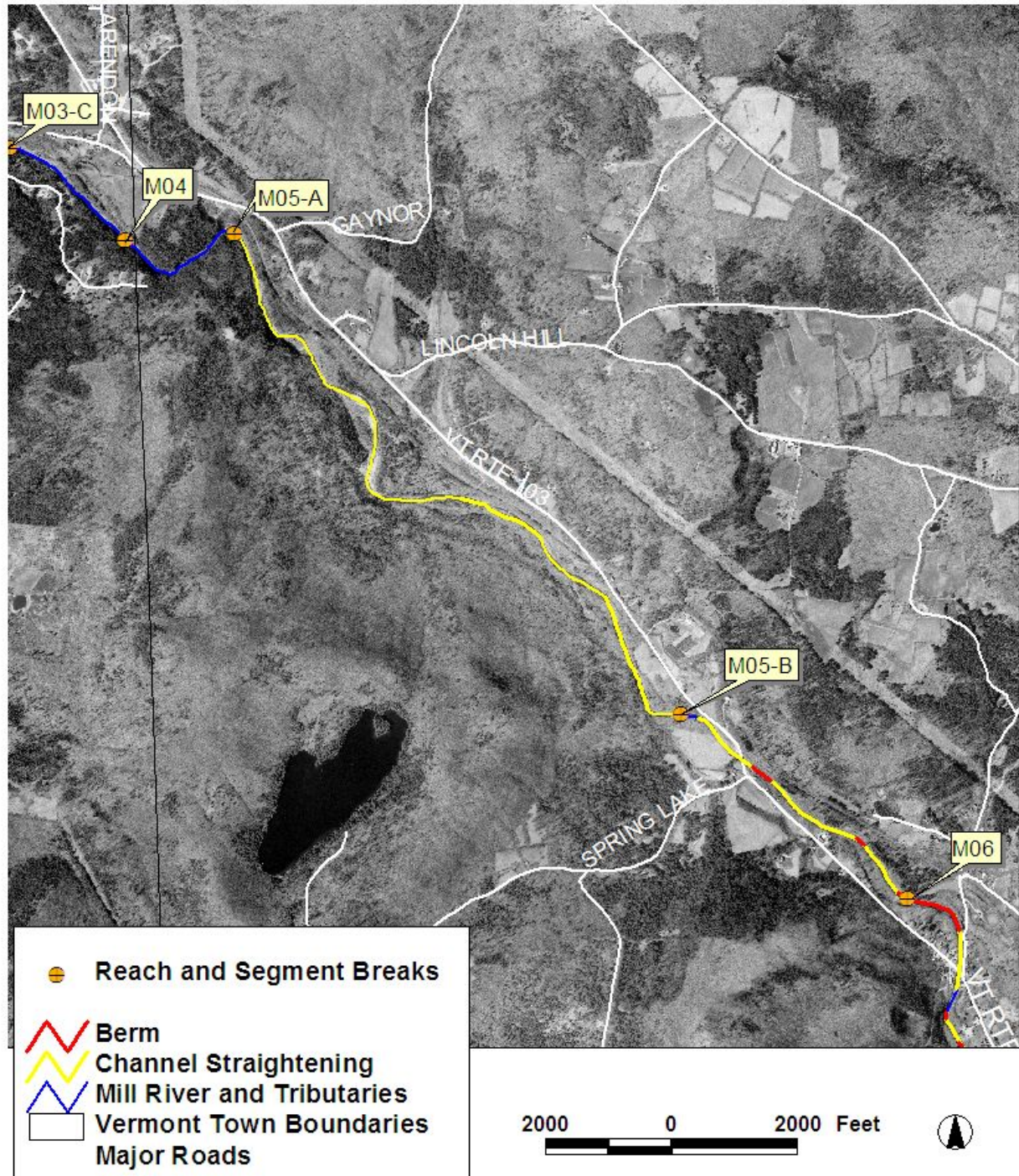


Figure 17: Overview of reaches M03-C through M06 and channel straightening and berming.



4.11 Reach M05

Mill River reach M05 is a long reach (16699 feet) that begins just below Cuttingsville Village and flows downstream to the beginning of the Upper Clarendon Gorge near the Long Trail suspension bridge. RRD divided the reach into two segments based on major shifts in corridor encroachment and channel dimensions as the stream transitions from the residential, commercial, and agricultural development near Cuttingsville and enters a forested corridor.

Segment B:

M05-B, as with many segments upstream, is heavily influenced by recent and historic channel management activities including berming, armoring, dredging and windrowing. Floodplain encroachment from VT 103 and residences and commercial development along with significant channel straightening have led to an incised stream that has departed from a reference C riffle-pool system (Figure 18). The B-type channel that now exists has less capacity to attenuate floodwaters and sediment and is a plane bed system with low quality habitat. A berm at the upstream end of the reach has prevented access to a major flood chute. Active major widening is occurring in response to channel incision. The planform and widening adjustments are limited by the valley wall, armoring, and dredging. Although there are significant corridor encroachments, some limited floodplain connectivity may be able to be restored in this reach in areas where structures are not currently located.



Figure 18. M05-B has been significantly altered through channel straightening, berming, armoring, and floodplain encroachment.

Segment A:

Mill River segment M05-A flows through a well forested corridor. Limited encroachment by the railroad track has impacted the right corridor. The channel has incised enough to abandon an old floodplain and begin to develop a juvenile



floodplain. The degree of channel incision is low enough so that the stream remains unentrenched and able to store flood waters during the largest events. A large mass failure within this reach is a source of fine sediment and gravels to the downstream system (Figure 19). This sediment appears to be assisting the stream in rebuilding bars and floodplain downstream. Several large flood chutes exist in the stream corridor indicating planform adjustment.



Figure 19. A large mass failure on the left bank is providing some sediment recruitment to help rebuild bars in the incised Mill River reach M05-A.

4.12 Reach M04

Mill River reach M04 encompasses the Upper Clarendon Gorge (Figure 20). The gorge begins at a sharp southwestward bend in the river where a Long Trail suspension bridge hangs from the bedrock cliffs on each side. The Mill River cuts through the Dalton Formation (a cambrian dolomite/conglomerate), the Mount Holly Gneiss, and the Cheshire Quartzite on its way through the gorge. Due to the bedrock this reach received only a partial Phase 2.



Figure 20. M04 consists of the Upper Clarendon Gorge.

RIVER SECTION 4: UPPER CLARENDON GORGE TO CONFLUENCE WITH THE OTTER CREEK

The final section of river (illustrated in Figure 21) begins below the Upper Clarendon Gorge (near the Kingsley Covered Bridge) in the town of Clarendon. From here down to the confluence with the Otter Creek, the Mill River flows through a few bedrock dominated reaches bordered by state and federally owned wooded landscapes before spilling onto the much broader Otter Creek valley bottom. Major significant impacts in this section include removal of riparian vegetation, channel straightening, dredging, and several undersized bridges.



Mill River Watershed Phase 2 Geomorphic Assessment Reach Overview and Channel Alterations Map

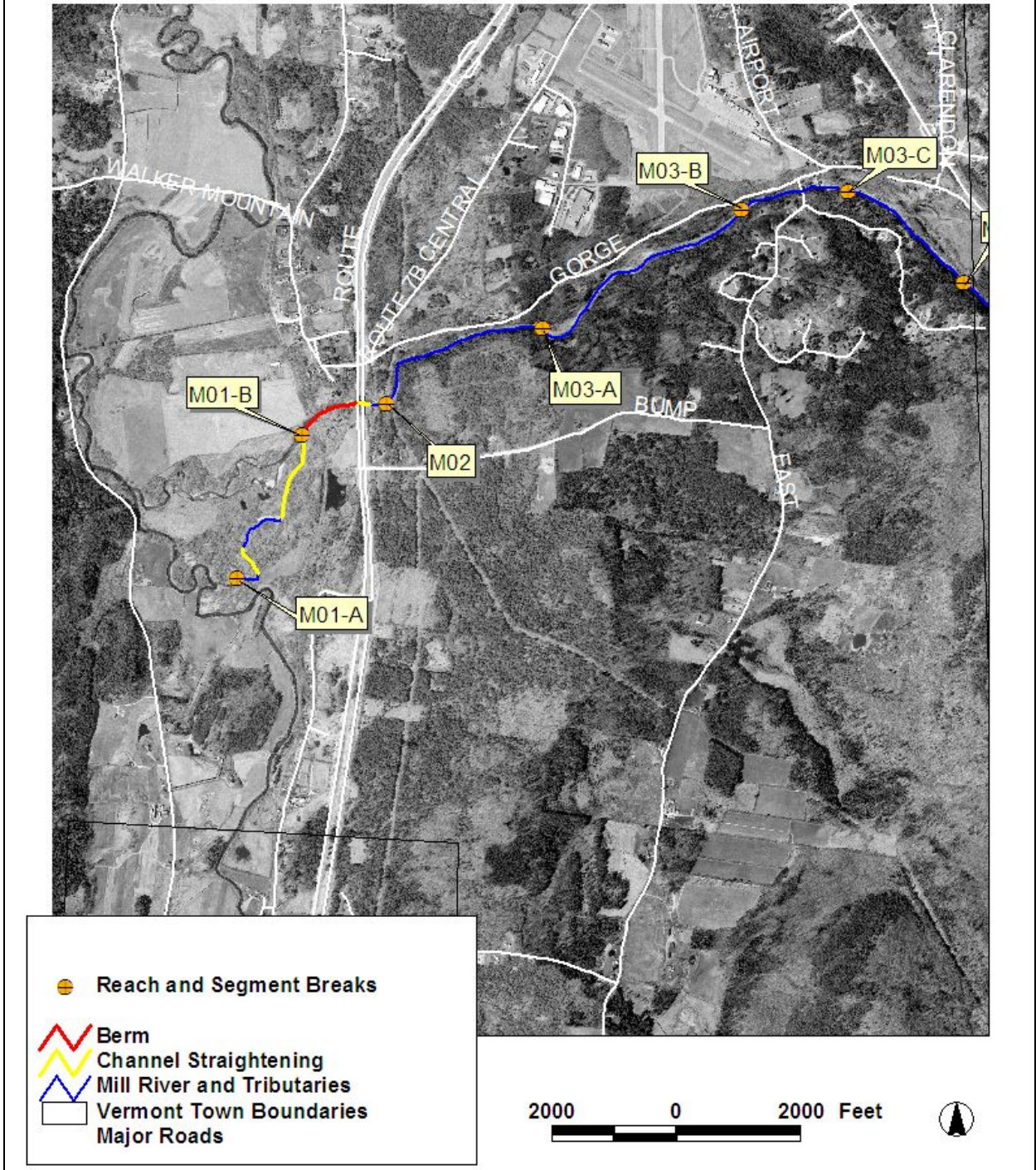


Figure 21: Overview of reaches M01 through M03 and channel straightening and berming.



4.13 Reach M03

Mill River reach M03 flows through residential and forested land in the town of Clarendon. The reach begins near the Clarendon/Shrewsbury town line at the end of the Upper Clarendon Gorge. RRD divided this reach into three segments due to significant changes in channel dimensions, entrenchment, and grade controls that occur throughout this reach.

Segment C:

This segment is located between the Upper Clarendon Gorge (a bedrock controlled section) and the bedrock controlled segment at the former Kingsley Mill site. Channel incision observed here may be a result of the river working back through sediments that were stored when there was a mill dam, or due to a sediment imbalance upstream. The Mill was in operation from 1882 until 1935. There are residences encroaching on the river corridor on the left bank, and land was cleared for agriculture on the right of the corridor. This reach was observed to be a B-type channel with a planebed form dominated by gravel substrates (Figure 21). This is expected to be the reference stream type despite major channel widening.



Figure 21. M03-C is a short plane bed segment between two bedrock grade controls.

Segment B:

Segment M03-B is a short bedrock controlled segment that includes the former Kingsley Mill dam site (Figure 22). Bedrock grade control and bedrock on most of the banks limited this segment to receiving only a partial Phase 2 assessment. Although some residential development has affected the riparian buffer, in general the bedrock has created a stable geomorphic condition in this segment.



Figure 22. M03-B is a bedrock controlled segment at the site of the former Kingsley Mill.

Segment A:

Mill River segment M03-A is also located between two bedrock grade controlled segments. Although this segment is slightly incised, it seems to be an area of sediment and floodwater attenuation, having large gravel bars, accessible floodplains and a forested buffer greater than 100 feet on both sides (Figure 22). As a result of the incision there is evidence of widening that has occurred in this segment. Minor planform and aggradation were observed as the stream rebuilds floodplain on both the left and right banks. This area will likely continue to be an important area in the lower Mill River watershed for sediment and floodwater attenuation.



Figure 22. M03-A is bordered by a forested buffer. Large bars of unvegetated sediment indicate recent adjustments in the channel.



4.14 Reach M02

Mill River reach M02 consists of the Lower Clarendon Gorge (Figure 23). The gorge is carved through the Cambrian Dalton formation and Cheshire Quartzite (Van Diver 1987). The Dalton formation lies on Precambrian rocks of the Green Mountain core at the upstream end of the gorge. Only a partial assessment was conducted for this reach due to the bedrock controlled channel.



Figure 23. M02 is the Lower Clarendon Gorge in Clarendon.

4.15 Reach M01

Reach M01 is a highly dynamic reach located at the foothills of the Green Mountains where the Mill River spills out onto the valley floor of the Otter Creek. Here the bedrock dominated channel of the Lower Clarendon Gorge gives way to the alluvial soils of the Otter Creek Valley. This area is a natural alluvial fan area for the Mill River. Channel migration, sediment deposition, and seasonal flooding were likely frequent occurrences in the predevelopment watershed. RRD divided this reach into two segments due to a significant amount of recent channel alteration that has occurred in the area just downstream from the Clarendon Gorge.

Segment B:

Mill River segment M01-B is a C-type channel by reference in a very broad valley. Significant channel management in the form of straightening, dredging, berming, and armoring has significantly altered the channel dimensions and entrenchment of this segment. The current incision ratio was observed to be 1.8 indicating that both berming and bed degradation have affected the nature of the channel. A landowner whose family has managed much of the surrounding land recounts the 1973 flood that washed out the railroad bridge. He noted that there was significant dredging of the



stream channel after the 1973 flood between the railroad bridge and Route 7. He also noted that in the 1950's the area below the railroad bridge was dredged for gravel to help build Route 103. Field observers from RRD and VTANR recorded that the channel has become a plane bed cobble dominated channel as a result of increased stream power (Figure 24).



Figure 24. M01-B has been significantly impacted by channel straightening, berming, dredging, and armoring.

Segment A:

M01-A is the lowest reach of the Mill River. This segment is located at a highly dynamic zone where floodwaters and sediment coming down from the relatively steep Green Mountain hillsides are released in the flat valley bottom of the Otter Creek. Scientists from RRD and VTANR observed a high degree of bank erosion and channel adjustment in this segment (Figure 25). The steambank material are composed of silts and clay near the confluence with the Otter Creek and the bank height increases significantly which is likely due to the influence of the Otter Creek. There is plenty of woody debris recruitment in this reach as the river migrates laterally pulling in trees. Although some areas are in need of a healthier riparian buffer, the habitat in this reach overall looks to provide good depth cover and structure. It is certain that continued investment in channel management will be necessary in order to keep the channel in its relative location, however this area is highly dynamic and should be expected to always be undergoing extreme adjustment, especially during flood events as the river reacts to changes in sediment transport and hydrology in the watershed upstream.



Figure 25. M01-A is a gravel dominated reach near the confluence with the Otter Creek. Agricultural land use dominates the corridor. The river is undergoing extreme planform adjustment and major widening and aggradation.

APPENDIX C

BRIDGE AND CULVERT REPORT

Mill River

Rutland County, Vermont



Bridge and Culvert Report

February 17, 2009

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Mill River Rutland County, Vermont Bridge and Culvert Report

EXECUTIVE SUMMARY

- Round River Design was retained by the Rutland Regional Planning Commission (RRPC) to conduct a Bridge and Culvert Assessment of the Mill River Watershed limited to the Phase 2 assessed reaches (M01-M15 and T2.01).
- The Vermont Agency of Natural Resources (ANR) Bridge and Culvert Assessment and Survey Protocols (dated July 2007) were used to conduct a rapid assessment of stream crossings. The assessment results were entered into the ANR bridge and culvert database. A photo log of the structures was created.
- The objective of the analysis is to identify structures whose replacement would lend to geomorphic stability at a reach or segment scale, as well as structures that may be at risk of failure.
- A total of 15 bridges within the towns of Clarendon, Shrewsbury, Wallingford, and Mount Holly were surveyed during August and September of 2007. The stream crossings included 10 structures on state roads, 3 bridges on town roads, and 2 privately owned crossings.
- All of the structures surveyed were red flagged by the ANR's database for having an attribute that may lend to them being geomorphically incompatible and potentially increasing flood and fluvial erosion hazards and/or stream instability.

1.0 INTRODUCTION

The need to cross the Mill River via bridge is imperative. The act of placing a bridge over the river has historically involved constructing stone footers onto which rest timbers and later iron and steel. The footers (or abutments) were placed close enough together so that a single large timber could span from one side to the other. In a large stream such as the Mill River, these abutments were often narrower than the natural channel. Today, even with new materials, bridge crossings tend to be constructed narrower than the river channel. This narrowing of the river becomes problematic when, during high flows, floodwaters back up due to the constriction. This causes flooding upstream of the bridge. This is worsened by debris that can accumulate at a constricted area including sediment which can accumulate upstream at unnatural locations further exacerbating instability. During flood conditions, pressure is increased on the downstream side of the bridge (similar to placing one's thumb on the end of a garden hose). The extra energy causes erosion and leaves a wide scoured area downstream of the bridge. Furthermore, physical changes to the river channel such as straightening and stone armoring leading up to and through a bridge, even in newer wider bridges, may prevent a river from migrating naturally across the valley bottom and may create fluvial erosion hazards.

Round River Design was retained by the Rutland Regional Planning Commission (RRPC) to conduct a Bridge and Culvert Assessment of the Mill River Watershed limited to the reaches that received a Phase 2 assessment (M01-M15 and T2.01). In total 15 structures were assessed according to



VTANR protocols for such characteristics as specific height and width, geomorphic and fish passage data, nearby vegetation, and evidence of wildlife. The assessment results were entered into the ANR bridge and culvert database. The objective of this analysis is to identify structures that are potential barriers to fish and wildlife movement and/or are flood or erosions hazards.

2.0 METHODOLOGY

The Bridge and Culvert Assessment and Survey Protocols specified in Appendix G of the Vermont Stream Geomorphic Assessment Handbook (Vermont Agency of Natural Resources 2007) were followed. All assessment data were recorded on the Agency of Natural Resources (ANR) "Bridge and Culvert Assessment – Geomorphic & Habitat Parameters" data sheet, and were entered into the Bridge and Culvert database. ArcView shapefiles of stream crossings for the State of Vermont "TRANS_TRANSTRUC_POINT" were downloaded from the Vermont Center for Geographic Information. This shapefile includes stream crossings on state and town roads. With the exception of a private road in Mount Holly and two railroad bridges, all other structures were the maintenance responsibility of the town or state.

The bankfull channel width was measured in areas close to, but uninfluenced by, each of the structures. This measurement was compared to the Vermont Regional Hydraulic Geometry Curves as a QA check. The channel measurements were then compared with structure widths to determine whether the structures created a constriction in the channel and/or floodplain of the Mill River. Latitude and longitude at each of the structures was determined using orthophotographs and ArcView GIS. The assessment included photo documentation of the inlet, outlet, upstream, and downstream of each of the structures.

3.0 RESULTS

Fifteen bridges were included in the bridge and culvert assessment (see Figure 2). As shown on in Table 1 and 2, all 15 structures were flagged on the ANR's bridge failure mode report for some geomorphic incompatibility. In particular a number of bridge and culverts were observed to be considerably narrower than the existing bankfull width subsequently causing instability in the river. Narrow crossings reduce sediment transport capacity and disconnect floodplains from the river channel. In particular need of replacement based on the problems observed and their percent bankfull width are the Route 155 Bridge in East Wallingford and the Barlow Road Bridge in Mount Holly. Also the two structures located on T2.01 were found to be undersized. From a technical measurement (from footing to footing) the railroad bridge on M11-A does not appear to be a problem, however, the channel width of the river from bridge abutment to the Route 155 embankment was only 39 feet (70% reference channel width) and should also be considered a problem structure (Figure 1).



Figure 1: The railroad bridge span on M11-A is adequate for the Mill River (red line), however, location of Route 155 in relation to the bridge and the river creates a channel constriction between the bridge abutment and the road (yellow line).

TABLE 1: MILL RIVER BRIDGES: PROBLEMS AND POTENTIAL FAILURE MODES																	
Reach	Road	Type	F1	F2	F3	F4	F5	F6	P1	P2	P3	P4	P5	P6	P7	Width	
M15	Private road	Bridge	-	-	-	X	-	X	X	X	X	X	-	-	X	111 %	
M14	BARLOW RD	Bridge	-	-	-	-	-	-	-	-	-	-	-	-	X	77 %	
M11-B	ROUTE 155	Bridge	-	X	X	X	X	X	-	X	X	-	-	-	X	54 %	
M11-A	Railroad	Bridge	X	-	-	X	-	X	X	-	-	-	-	-	-	190 %	
M10	ROUTE 140-EAST	Bridge	-	-	-	X	-	X	X	-	X	X	-	-	X	172 %	
M10	VILLAGE ST	Bridge	-	-	X	X	-	X	-	-	X	-	-	-	X	253 %	
M08	Railroad	Bridge	-	-	X	-	-	X	X	X	X	-	-	-	X	163 %	
M06	VT RTE 103	Bridge	-	-	-	-	-	X	-	-	-	-	X	-	X	171 %	
M05	VT RTE 103	Bridge	-	-	-	X	-	X	X	-	X	X	-	-	X	237 %	
M03-B	EAST ST	Bridge	-	-	X	-	-	-	-	X	-	-	-	-	X	85 %	
M01-B	ROUTE 7	Bridge	-	-	-	X	-	X	X	-	-	X	-	-	X	364 %	
M01-B	ROUTE 7	Bridge	-	-	-	X	-	X	X	-	-	X	-	-	X	364 %	
M01-B	Railroad	Bridge	-	-	-	X	-	X	X	-	-	X	-	-	X	154 %	
T2.01-B	BOWLSVILLE RD	Bridge	-	X	X	X	X	-	-	X	X	-	-	-	X	50 %	
T2.01-A	ROUTE 140-EAST	Bridge	-	X	X	X	X	X	X	X	-	X	X	-	X	61 %	
Failure Modes																	
F1	Concern for structure due to fluvial condition or process																
F2	Potential failure due to out-flanking																
F3	Potential failure due to scour																
F4	Potential failure due to ice or debris jam																
F5	Structure related damage due to flooding of adjacent property																



F6	Structure related damage due to erosion of adjacent property
Existing Problems	
P1	Upstream sediment deposit
P2	Upstream Scour and/or erosion present
P3	Downstream Scour and/or erosion present
P4	Inlet obstruction present
P5	Poor location or alignment
P6	Beaver activity
P7	Floodplain filled entirely or partially by roadway approaches
Width	Structure width divided by channel width as a percent (% bankfull width)

TABLE 2: MILL RIVER BRIDGES: Failure Modes Report – Problem Causes

Reach	Road	Bankfull Width %	Upstream Sediment Deposition			Upstream Scour and Erosion			Downstream Scour and Erosion				Poor Location and Alignment			
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C12	C13	C14	
M15	Private road	154 %	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
M14	BARLOW RD	85 %	No	No	No	No	No	Yes	No	No	No	No	No	No	No	No
M11-B	ROUTE 155	364 %	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
M11-A	Railroad	364 %	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
M10	ROUTE 140-EAST	111 %	Yes	No	No	No	Yes	No	No	Yes	No	No	No	No	No	No
M10	VILLAGE ST	77 %	No	No	No	No	No	No	No	No	No	No	No	No	No	No
M08	Railroad	50 %	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	No
M06	VT RTE 103	54 %	No	No	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
M05	VT RTE 103	171 %	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes
M03-B	EAST ST	237 %	Yes	No	No	No	No	No	No	Yes	No	No	No	No	No	No
M01-B	ROUTE 7	190 %	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No
M01-B	ROUTE 7	163 %	No	No	Yes	No	No	Yes	Yes	No	Yes	No	No	No	No	No
M01-B	Railroad	172 %	Yes	No	No	No	No	No	No	Yes	No	No	No	No	No	No
T2.01-B	BOWLSVILLE RD	61 %	Yes	Yes	No	Yes	Yes	No	No	No	No	No	Yes	No	No	No
T2.01-A	ROUTE 140-EAST	253 %	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
		154 %	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No

Explanation of codes used in table header			
Upstream Sediment Deposition		Upstream Scour and Erosion	
C1	Opening obstructed by sediment	C4	Bank armoring failing
C2	Sediment deposits >= half bankfull	C5	Bank erosion high
C3	steep riffle upstream	C6	Scour under structure
		Downstream Scour and Erosion	
		C7	Bank armoring failing
		C8	Bank erosion high
		C9	Scour under structure
		C10	Banks higher downstream than upstream
		C11	Culvert outlet is cascade or freefall
		Poor Location or Alignment	
		C12	Stream approach angle is sharp bend
		C13	Located at significant valley break
		C14	Avulsion follow road



In order to assist the towns with priorities for replacement of these structures, priority lists were generated using the information and photographs taken during the assessment. The bridge span and the culvert diameter as a percentage of the channel width were used as a first cut in prioritizing the structures for replacement. Bridges and culverts with channel widths of approximately 70 percent of the bankfull width or less, which were significantly impeding natural sediment transport were placed in Category 1.

Category 2 structures included the remaining structures with percent bankfull widths less than 100%, which were not selected for Category 1. The priority 2 category is of lower priority for replacement, but still contains structures that may be incompatible in terms of sediment transport. Category 3 structures have a percent bankfull width which is greater than or equal to 100 percent.

3.1 Priority One Structures

The category 1 structures are summarized below in Table 1, and are identified on the map in Figure 3.

Table 3: Priority 1 Structures for Replacement			
Town	Location	% BF Width	Problems Noted By RRD
Mount Holly	Bowlsville Road North	50	Scour downstream of structure, riprap around outlet failing
Mount Holly	VT Route 155	54	Channel constriction
Wallingford	Rte 140 East	61	Downstream undermining, high debris jam potential

3.2 Priority Two Structures

Based on the results of the ANR Bridge and Culvert Assessment, the structures with percent bankfull widths of less than 100% (but greater than 70%) were placed in the list of priority two structures because they did not appear to be a high priority in terms of sediment transport. One additional structure was added due to concerns raised during field observations. A brief explanation of these structures is provided below.

Table 4: Priority 2 Structures for Replacement			
Town	Location	% BF Width	Problems Noted By RRD
Mount Holly	Barlow Road	77	Scour downstream of structure, riprap around outlet failing
Clarendon	East Street	85	Channel constriction



3.3 Priority Three Structures

All of the remaining structures with culvert diameters or spans of greater than 100 percent bankfull width were placed in category three. At this time, the priority 3 structures are a lower priority for replacement. In the future, replacement of these structures should include consultation with the Vermont State River Management Program in order to ensure geomorphic compatibility.

4.0 RECOMMENDATIONS

Due to the significant impact that undersized structures can have on the stability, habitat, and flood hazard of the Mill River, the towns, state, and federal government should work together to replace and/or retrofit undersized bridges and culverts and ensure all new structures are sized for geomorphic compatibility.

REFERENCES

Vermont Agency of Natural Resources. 2007. Vermont Stream Geomorphic Assessment, Appendix G: Bridge and Culvert Assessment and Survey Protocols. Waterbury, Vermont

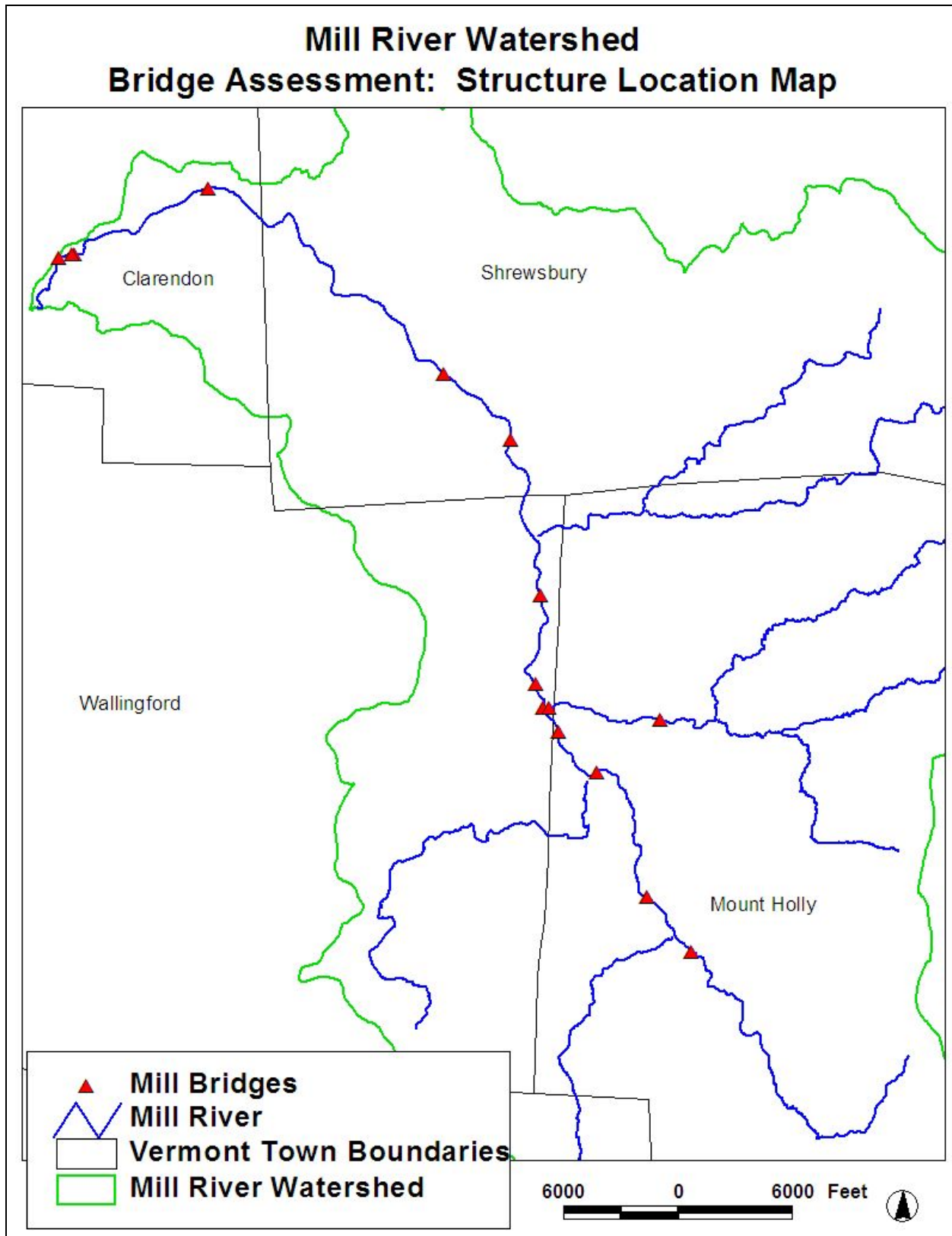


Figure 2. Bridges and culverts assessed during fall 2007 by Round River Design using the ANR protocol.



Mill River Watershed Bridge Assessment: Priority One Structures

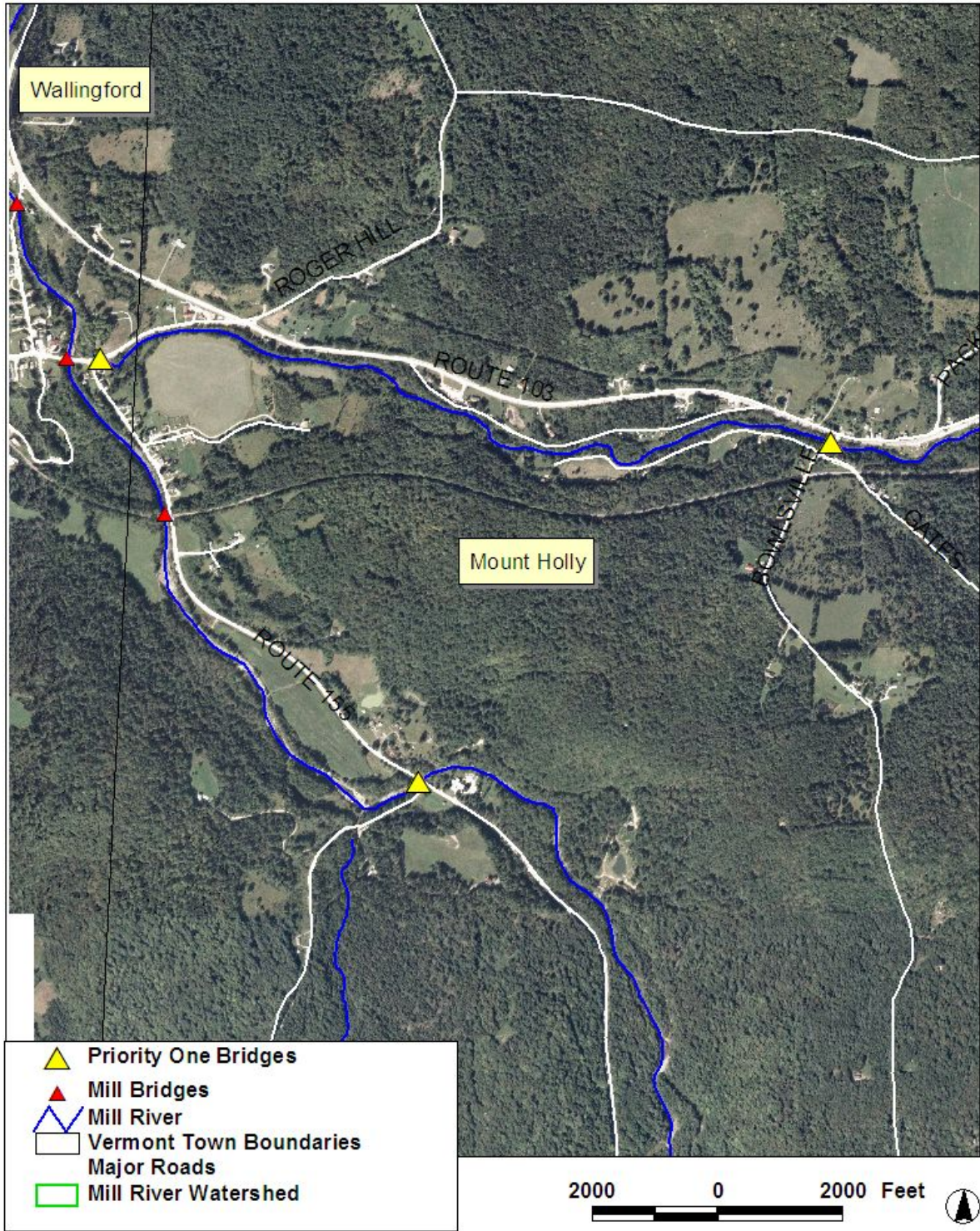


Figure 3. Stream crossings in the Mill River watershed considered to be high priority for replacement due to geomorphic incompatibility.

APPENDIX D

Channel Evolution Models

(Vermont Agency of Natural Resources, Appendix C, May 2007)

Channel Evolution Models

F-stage Channel Evolution Process

The capital letters used throughout the following discussions refer to the stream types (Rosgen, 1996) typically encountered as the channel form passes through the different stages of channel evolution. The F-stage adjustment process begins where the streams are not entrenched and have access to a floodplain at the 1-2 year flood stage. Moderately entrenched, semi-confined “B” streams may also go through an F-stage channel evolution. This channel evolution model (CEM) is based on the assumption that the stream has a bed and banks that are sufficiently erodible so that they can be shaped by the stream over the course of years or decades. Streams beginning this process are typically flowing in alluvium or other materials that may be eroded by an increase in stream power. As the incision process continues, they may degrade to bedrock or glacial till materials. When a stream with a low width to depth ratio (“E” stream types) goes through this process, the sequence of stream types may be **E-C-F-C-E** (other forms may include **E-C-G-F-C-E** or **C-G-F-C** or **C-F-C** or **C-B-F-B-C** or **B-G-F-B** or **B-G-F** or **C-B-C**).

Stage I - Channel in regime with access to floodplain or flood prone area at discharges at and above the average annual high flow. Planform is moderate to highly sinuous; supportive of energy dissipating bed features (steps, riffles, runs, pools) essential to channel stability (B, C and E Stream Types). Channel slope (vertical drop in relation to length) generates flow velocities and stream power in balance with the resistance of stream bed and bank materials. Sediment transport capacity in equilibrium with sediment load.

Stage II - Channel has lost access to its floodplain or flood prone area, at its historic bankfull discharge, through a bed degradation process or floodplain build up. Stream has become more entrenched as discharges in excess of the annual high flow are now contained in the channel (B or G or F Stream Type). Channel slope is increased with commensurate increase in velocity and power to erode the stream bed and banks (boundary materials). The result of preventing access to the floodplain and containing greater flows in the channel is to increase the stream’s power that must be resisted by the channel boundary materials; i.e., the rocks, soil, vegetation or man-made structures that make up the bed and banks of the river. Plane bed may begin to form as head cuts move upstream and step/riffle materials are eroded.

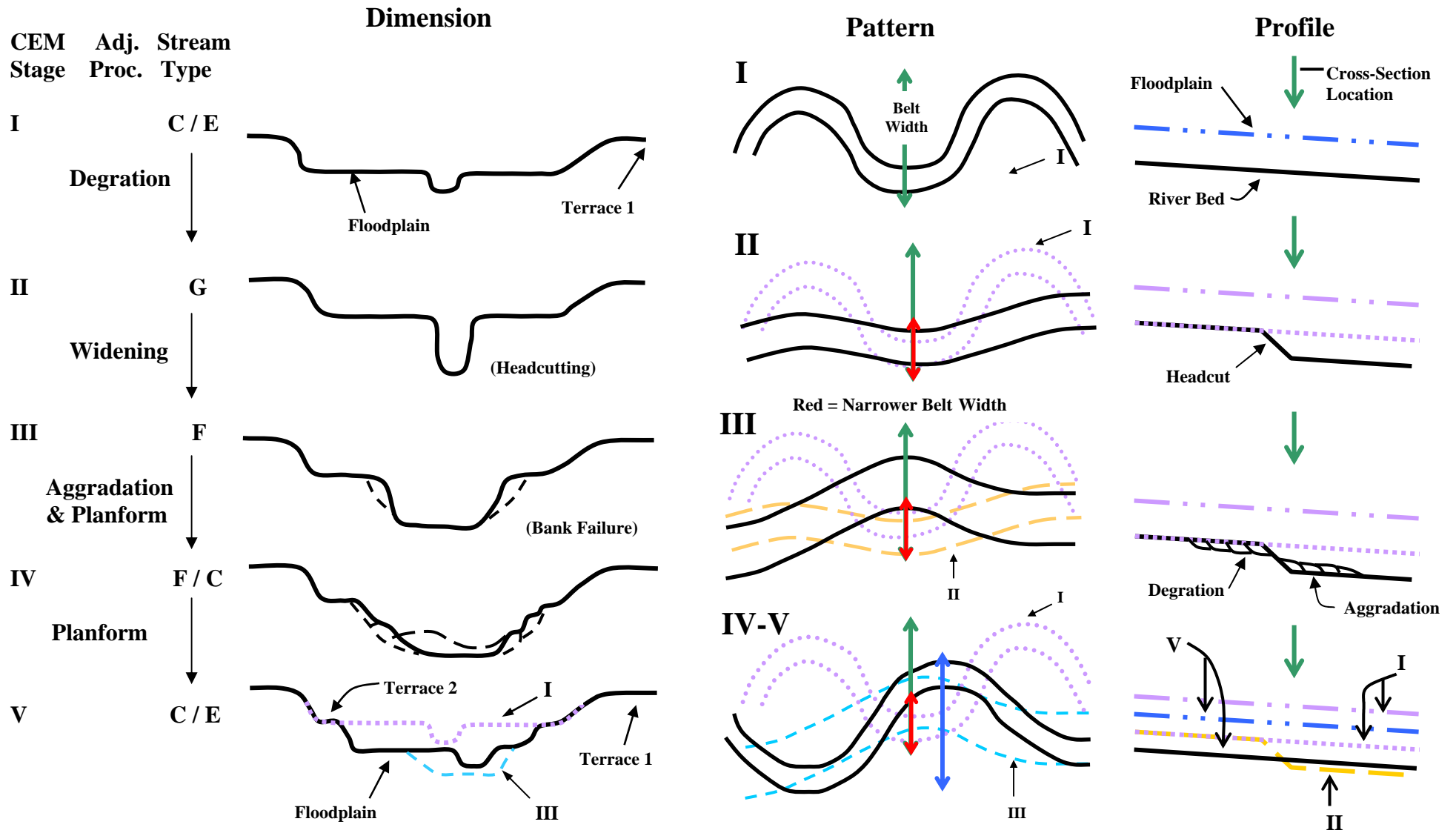
Stage III - Channel is still entrenched, widening and migrating laterally through bank erosion caused by the increased stream power (B or G or F Stream Type). The system regains balance between the power produced and the boundary materials as sinuosity increases and slope decreases. There are profound physical adjustments that occur upstream and downstream from the site of alteration as bed degradation (head cuts) migrates up through the system and aggradation in the form of sedimentation occurs downstream. Stream bed largely becomes a featureless plane bed.

Stage IV - Channel dimension and plan form adjustment process continues. Channel width begins to narrow through aggradation and the development of bar features. The main channel may shift back and forth through different flood chutes, continuing to erode terrace side slopes as a juvenile floodplain widens and forms. Weak step/riffle-pool bed features forming. Transverse bars may be common as planform continues to adjust. At Stage IV, erosion may be severe. Historically, channels have been dredged, bermed, and/or armored at this Stage pushing the process back to Stage II or III.

Stage V - Channel adjustment process is complete. Channel dimension, pattern, and profile are similar to the pre-adjustment form but at a lower elevation in the landscape (B, C and E Stream Types). Planform geometry, longitudinal profile, channel depth, and bed features produce an energy grade that is in balance with the sediment regime produced by the stream’s watershed.

Higher gradient, more entrenched streams (“A” or “B” stream types) with erodible beds also go through channel evolution processes that involves bed degradation. In these cases, the floodplain forming stages may be comparatively minor. A lowering of the bed elevation is more quickly followed by a re-sloping of the banks until the appropriate energy grade is achieved.

F-stage Channel Evolution Process (VTDEC-Modified from Schumm, 1977 & 1984 and Thorne et al, 1997)



D-stage Channel Evolution Process

Only use the D stage CEM where the stream has no opportunity to incise. If the stream has incised and has now hit bedrock or clay and is currently widening, you would still use the F stage CEM.

The capital letters used throughout the following discussions refer to the stream types (Rosgen, 1996) typically encountered as the channel form in the different stages of channel evolution. The difference between F and D-stage channel evolution processes is the degree of channel incision. In D-stage channel evolution, the dominant, active adjustment processes is **aggradation**, widening, and plan form change. In some situations, the stream may not experience any degradation because its bed is significantly more resistant to erosion than its banks. The process may start with limited vertical adjustment and goes right into aggradation and a lateral adjustment processes. Stream with low width to depth ratios ("E" Stream Types) may also go through this process.

Stage I - Channel in regime with access to floodplain or flood prone area at discharges at and above the average annual high flow (B, C and E Stream Types). Plan form is moderate to highly sinuous; supportive of energy dissipating bed features (steps, riffles, runs, pools) essential to channel stability. Channel slope (vertical drop in relation to length) generates flow velocities and stream power in balance with the resistance of stream bed and bank materials. **Then either of the following Stage II scenarios may occur:**

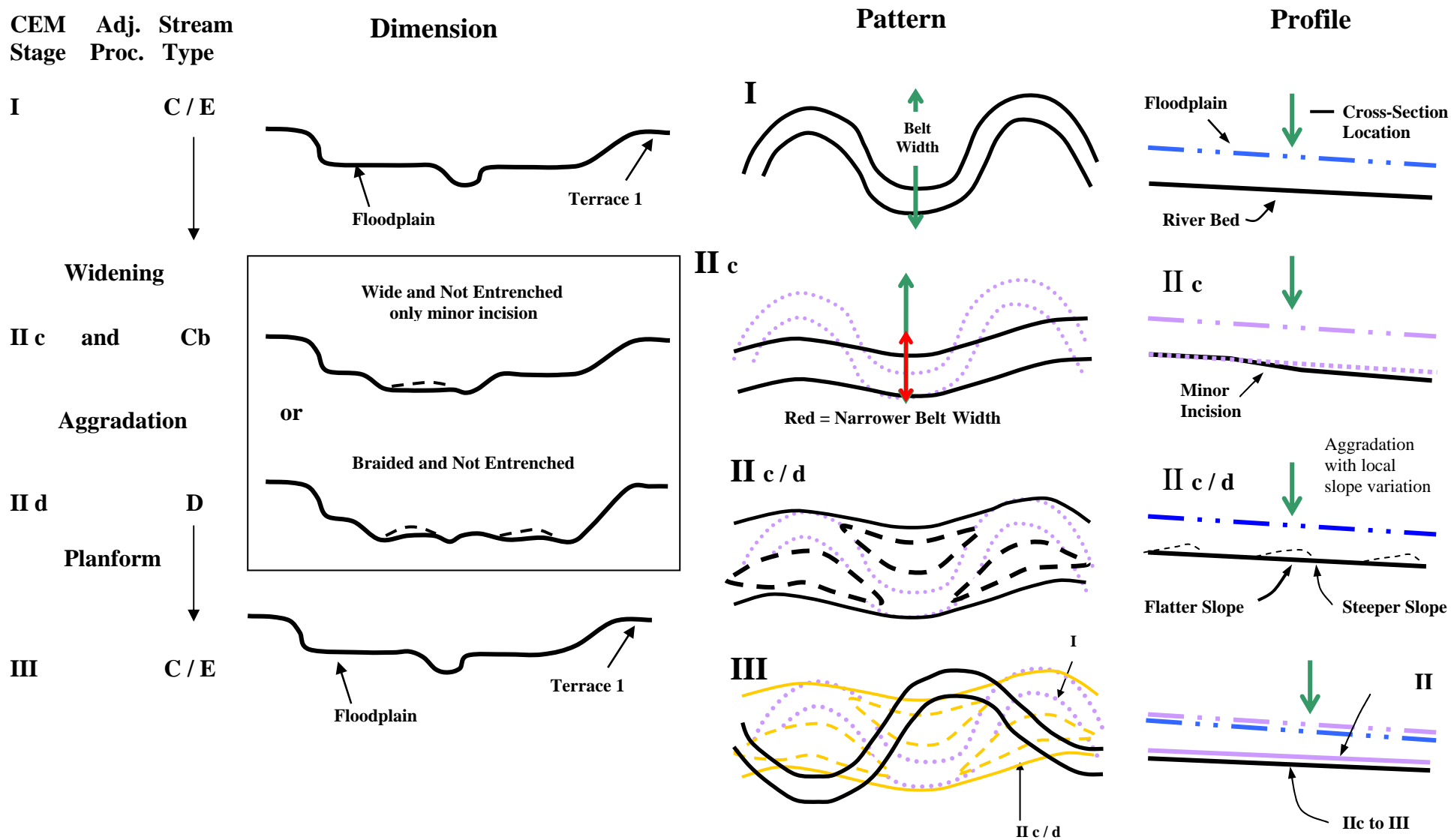
Stage IIc Steeper gradient may be imposed through activities such as channelization, but due to the resistance of the bed material, the stream has not incised significantly or lost access to its floodplain (remaining a "C" Stream Type). Channel is widening and migrating laterally through bank erosion caused by the increased stream power. The balance between stream power and boundary materials is re-established when the slope flattens after a process of channel lengthening and increased sinuosity. Stream bed may be a combination of poorly defined riffle-pool and plane bed features.

Stage II d Channel becomes extremely depositional and becomes braided with water flowing in multiple channels at low flow stage ("D" stream type). Dimension and plan form adjustment processes continue. Channel width begins to narrow through aggradation and the development of bar features. The main channel may shift back and forth through different channels and chute cut-offs, continuing to erode banks or terrace side slopes. Riffle-pool bed features develop as single thread channel begins forming. Transverse bars may be common as planform continues to adjust.

Stage III Channel adjustment process is complete (back to a B, C or E stream type). Channel dimension, pattern, and profile are similar to the pre-adjustment form. May or may not be at a lower elevation in the landscape. Planform geometry, longitudinal profile, channel depth, and bed features produce an energy grade (sediment transport capacity) that is in balance with the sediment regime produced by the stream watershed.

Important Notes: 1) The imposition of new constraints or changes at watershed, reach, or local scales, especially those related to large floods that energize the stream system with high flows of water, sediment, and debris, will affect the time scales associated with each stage of channel evolution. They may also have dramatic effects on the direction of a channel evolution process. The overlapping pulses of channel adjustment moving upstream and downstream in a watershed often makes the pinpointing of a specific channel evolution stage complicated. 2) Bedrock-controlled reaches in Vermont are presumed to be relatively fixed for the purposes of these protocols as little bed or bank erosion can be expected even over a century. Such reaches may, however, dramatically change or evolve due to rapid or catastrophic avulsions of the flow onto more erodible sediments nearby, leaving the bedrock channel wholly or partially abandoned.

C-D-C Channel Evolution Process (VTDEC-Modified from Schumm, 1977 & 1984 and Thorne et al, 1997)



APPENDIX E

FLUVIAL EROSION HAZARD ANALYSIS

Mill River

Clarendon, Shrewsbury, Wallingford, and Mount Holly Rutland County, Vermont



Fluvial Erosion Hazard (FEH) Analysis

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Mill River

Clarendon, Shrewsbury, Wallingford, and Mount Holly Rutland County, Vermont

Fluvial Erosion Hazard (FEH) Analysis

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Mill River Rutland County, Vermont Fluvial Erosion Hazard (FEH) Analysis

1.0 EXECUTIVE SUMMARY

- Round River Design was retained by the Rutland Natural Resource Conservation District to analyze a draft Fluvial Erosion Hazard (FEH) Zone developed for the Mill River Phase 2 study area by the Vermont Agency of Natural Resources.
- The Vermont Agency of Natural Resources FEH Zone Analysis utilized Phase 2 data collected during the autumn of 2007 by Round River Design and a valley wall verification performed by VTANR staff scientists.
- The objective of the analysis is to compare the proposed FEH zone to the existing zoning, structures, and conserved lands in order to determine the effect of the FEH zoning on property along the Mill River.
- The greatest concentration of existing structures lie in the village centers of East Wallingford and Cuttingsville. Here FEH zoning would affect the greatest number of landowners.
- Many reaches have little or no existing structures in the FEH corridor. Designation of an FEH corridor in reaches with little or no existing structures would be a proactive approach that may assist in long term channel stability.
- The Towns of Clarendon, Shrewsbury, Wallingford, and Mount Holly should work with the VTANR and the Rutland Regional Planning Commission to consider the adoption of a FEH Overlay District into their Town Regulations.
- Education about the FEH corridor and erosion hazard risks would be a valuable service for landowners.

2.0 INTRODUCTION

Round River Design was retained by the Rutland Natural Resource Conservation District (RNRCD) to develop a River Corridor Plan for the Mill River. The Vermont Agency of Natural Resources (VTANR) uses the “river corridor” as a primary tool in its avoidance strategy to restore and protect the natural values of rivers and to minimize flood damage. River corridors consist of lands adjacent to and including the present channel of a river. The adjacent lands included in a



“corridor” are those that are capable and perhaps likely to be occupied by the channel itself as the river meanders within a valley bottom over time (For a technical description of how they are delineated see “River Corridor Protection Guide: Fluvial Geomorphic-Based Methodology to Reduce Flood Hazards and Protect Water Quality” (VTANR 2008)). River corridor planning is conducted in Vermont to remediate the river instability that is largely responsible for erosion and flooding conflicts, increased sediment and nutrient loading to surface waters, and a reduction in river habitat (VTANR 2007). Reducing current and future near-stream investment and achieving natural stream stability promotes a sustainable relationship with rivers over time, minimizing the costs associated with floods (\$14 Million annually average in Vermont) and maximizing the benefits of clean water and healthy ecosystems (VTANR 2008). The Mill River Corridor Plan is derived significantly from data collected from a stream geomorphic assessment project. Stream geomorphic assessments provide information about the physical condition of streams and the factors that influence their stability.

As a component of the River Corridor Plan, Round River Design was retained by the Rutland Natural Resource Conservation District (RNRCD) to analyze the draft Fluvial Erosion Hazard (FEH) Zone of the Mill River (limited to the reaches that received a Phase 2 assessment (M01-M15 and T2.01) (see Figure 1). The draft FEH Zone was created by the Vermont Agency of Natural Resources following the Phase 2 Geomorphic Assessment (Blazewicz, 2007). The objective of this analysis is to compare the draft FEH zone to the existing zoning, structures, and conservation lands within the Mill River corridor to determine the effect of adoption of FEH Zoning on these properties.

Kari Dolan of the VTDEC developed the FEH overlay zone using the Stream Geomorphic Assessment Tool (SGAT) and the VTANR FEH approach (Vermont Agency of Natural Resources 2005a and 2008). Data regarding the current condition of the stream channel was provided by Round River Design and formed the backbone of the FEH zone development.

2.1 Fluvial Erosion Hazard Zones

Fluvial Erosion Hazard Zone development is a priority of the Vermont River Management Program. The reason is straightforward; of all types of natural hazards experienced in Vermont, flash flooding represents the most frequent disaster mode and has resulted in by far the greatest magnitude of damage suffered by private property and public infrastructure. While inundation-related flood loss is a significant component of flood disasters, the predominate mode of damage is associated with the dynamic, and oftentimes catastrophic, physical adjustment of stream channel dimensions and location during storm events due to bed and bank erosion, debris and ice jams, structural failures, flow diversion, or flow modification by man made structures. These channel adjustments and their devastating consequences have frequently been documented wherein such adjustments are related to historic channel management activities, floodplain encroachments, adjacent land use practices and/or changes to watershed hydrology associated with land use and drainage.

The purpose of defining Fluvial Erosion Hazard Zones is to prevent increases in fluvial erosion resulting from uncontrolled development in identified fluvial erosion hazard areas; minimize property loss and damage due to fluvial erosion; prohibit land uses and development in fluvial erosion hazards areas that pose a danger to health and safety; and discourage the acquisition



of property that is unsuited for the intended purposes due to fluvial erosion hazards (VTANR 2005b).

The basis of a Fluvial Erosion Hazard Zone is a defined river corridor which includes lands adjacent to and including the course of a river. The width of the corridor is defined by the lateral extent of the river meanders, called the meander belt width, which is governed by valley landforms, surficial geology, and the length and slope requirements of the river channel. The width of the corridor is also governed by the stream type and sensitivity of the stream. River corridors, further defined through VTDEC Geomorphic Assessments (VTANR 2007), are intended to provide landowners, land use planners, and river managers with the area of land which would accommodate the meanders and slope of a balanced or equilibrium channel, which when achieved, would serve to maximize channel stability and minimize fluvial erosion hazards.

NOTE: It should be noted that the glacial history of the Mill River may have created soils along valley side slopes and river terraces that are extremely erodable. Although a Fluvial Erosion Hazard Zone may protect against hazards in the beltwidth of the river, where the Mill River runs up against its valley walls, there may be danger of landslide hazard. A discussion of landslide hazard should be included with any discussion of adoption of Fluvial Erosion Hazard Zones.

2.2 Riparian Protection

It is also important to note that depending on a landowner's goals the area deserving consideration for conservation, restoration, or protection from encroachment may extend beyond delineated FEH zones. For example, vegetated buffers measuring back from the top of an existing stream bank may extend beyond an FEH zone in order to capture some of the other ecological and water quality benefits such as habitat for wildlife, water quality improvements, and landslide hazard protection. Riparian landowners are encouraged to work on a voluntary basis with the Rutland Natural Resource Conservation District (RNRCD) to protect and enhance riparian buffers along the Mill River. Some federal and state programs may assist landowners in funding streamside reforestation projects.

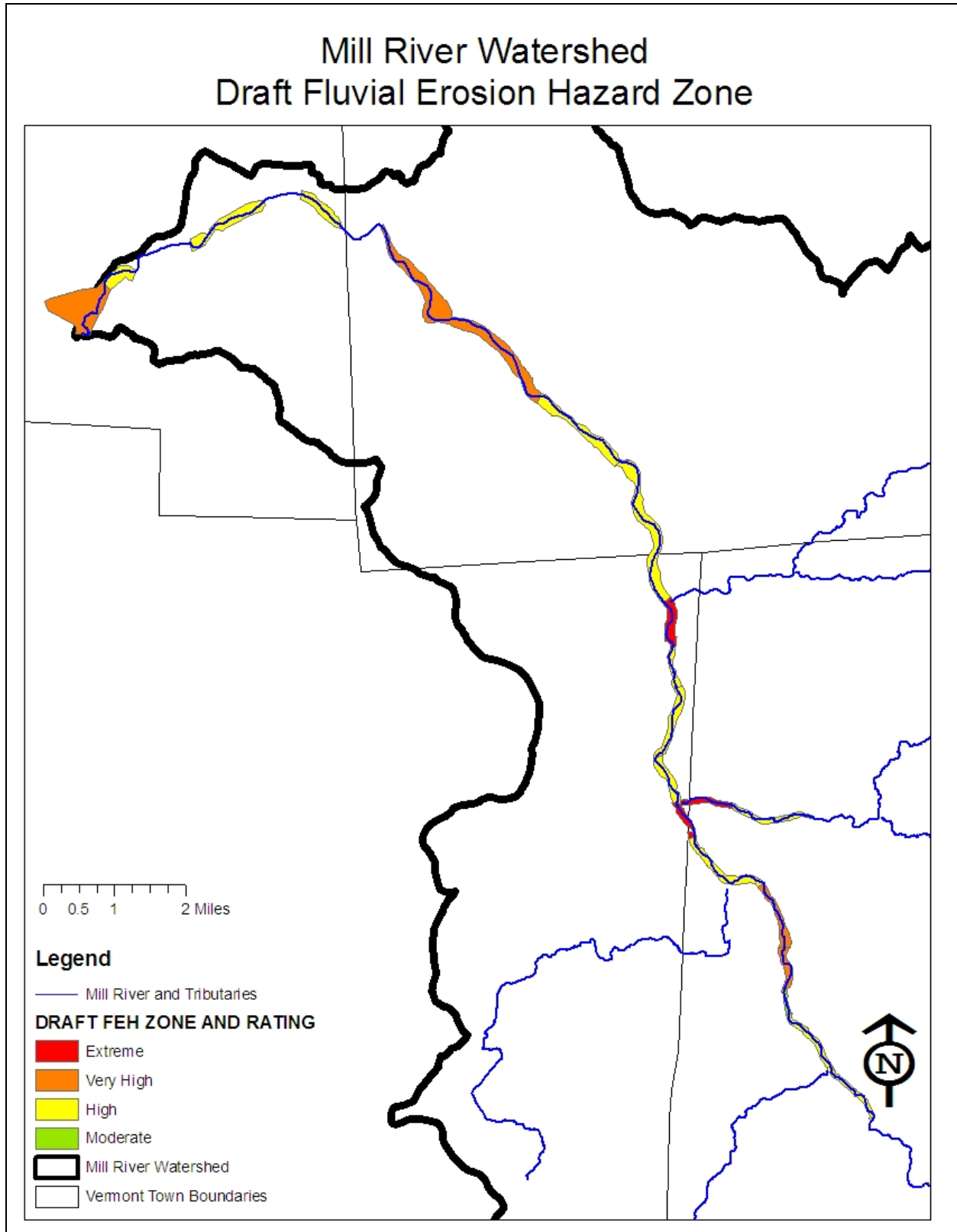


Figure 1: Draft FEH Zone developed by the VTANR.



3.0 METHODOLOGY

Utilizing the FEH Zone drafted by the VTDEC, Round River Design conducted a reach by reach review to investigate how adoption of an FEH zone would interact with existing zoning, as well as to investigate how adoption may affect landowners. In order to conduct this analysis, an Emergency 911 dataset of existing structures was obtained from the Vermont Center for Geographic Information website. Additionally, zoning maps were obtained from the Rutland Regional Planning Commission.

FEH Sensitivity Rating	FEH Corridor Width (related to reference channel width)	Typical Mill River Setting
Very Low	Equal to reference channel width	Bedrock controlled channels (gorges)
Low	Equal to reference channel width	None in this study
Moderate	Four channel widths	Semi-confined channels with good geomorphic stability
High	Six channel widths (8+ channel widths on "E" type streams)	Moderate sloped channels, may be somewhat confined, that have some but limited human impact
Very High	Six channel widths (8+ channel widths on "E" type streams)	Unconfined channels that have been significantly impacted by humans
Extreme	Six channel widths (8+ channel widths on "E" type streams)	Channels that have been significantly impacted and have undergone a stream type departure to a highly unstable channel

Below is reach-based summary of the current channel conditions and the opportunities and challenges for property protection as implicated by an FEH district overlay. Following the narrative summaries are recommendations for further actions that the Towns, VTDEC, and RNRCD may wish to pursue.

4.0 RESULTS

M15: Mount Holly

Current Condition

The most upstream reach, M15 is located at in a very broad valley in the town of Mount Holly. The land on the southwestern border of the stream is pasture land and it appears that the river through this reach had been straightened and pushed up against the right valley wall in order to make more room for agricultural activities. Deep down-cutting into the streambed material has occurred (incision ratio of 2) likely as a result of this straightening. This incision has significantly reduced the capacity of this reach to attenuate floodwater and sediment. Future lateral adjustment is expected to occur as the river works to redevelop floodplain in this reach.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	Construction of a new bridge was observed near the midway point of the reach.
<i>Assets and Liabilities</i>	The left corridor of the reach is currently being used for pasture and hay. Drainage work in the fields (observable in aerial photographs) indicates that much of the land may be wetland and therefore may have some protection from further development.

M14: Mount HollyCurrent Condition

Reach M14 begins where Meadow Brook enters the Mill River in the town of Mount Holly. Similar to M15, this reach borders recently agricultural (some no longer in production) land. The river through this reach appears to have been straightened and pushed up against the right (northeast) valley wall. An old meander scar is visible on aerial photographs just upstream from the Barlow Road Bridge indicating a level of historic sinuosity has been lost. Deep incision was observed (measured ratio of 3). Extensive widening and minor planform adjustments are occurring in the reach as the channel works to recover from the high level of incision.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	A single residence exists on the left bank. The structure itself, which sits atop a large terrace which is effectively the valley wall, lies just on the outside of the FEH delineated corridor. Although this house may be protected from fluvial erosion hazard due to the high embankment, there may be landslide potential at this site (which would require further geologic study). There is also a bridge crossing, Barlow Road, within this reach the width of which (77% that of reference bankfull width) may lead to sudden stream migration due to sedimentation during high flow events.
<i>Assets and Liabilities</i>	Much of the land is currently undeveloped. Several landowners own the properties along this reach.

M13: Mount HollyCurrent Condition

Reach M13-B is a short segment located where the valley wall of the Mill River narrows thereby creating a semi-confined channel by reference. The channel was found to be slightly incised. Some minor widening has occurred. Extreme adjustments are unlikely in this reach due to the



stable tendencies of B3 planebed streams, however, the potential for landslide hazard exists where the river runs along the toe of the valley wall on the left bank. Downstream, Mill River segment M13-A is a short segment located in a broad valley. The river is adjusting laterally through several flood chutes in this segment.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	Some development has occurred along the top of the left valley wall, however, the development is well above the floodplain and is only mentioned as the landowners in this reach are in close proximity to the stream and may have an impact on its water quality. These houses are also located on top of a steep valley wall and may have some erosion hazard risks. Currently most of the FEH Corridor is forested and owned by several landowners.
<i>Assets and Liabilities</i>	The well forested buffer in this corridor is an asset for the river as are the flood chutes and wetlands that will store some water and sediment during a large runoff event.

M12: Mount Holly

Current Condition

Mill River reach M12 begins upstream from Fowler Brook Road in the town of Mount Holly. The river flows through a well forested corridor in a broad valley. There is a great degree of instability in the channel. There were numerous active flood chutes documented as well as new gravel bars indicating both planform adjustment, widening, and aggradation as the channel works to redevelop new floodplain and tend to instability upstream.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	None
<i>Assets and Liabilities</i>	Currently forested.

M11-B: Mount Holly

Current Condition

Mill River segment M11-B captures an area where the valley walls open up and a tributary enters the Mill River from the west. In this segment, soils maps indicate that the parent material is alluvial suggesting the possibility that this area is an alluvial fan. There appears to have been a high degree of historic channel straightening that occurred in this reach, likely in order to increase the amount of agricultural land which dominates the right corridor.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	A major commercial lodging facility (and outbuildings) exists within the FEH corridor on the left bank upstream of the Route 155 bridge. In addition to the hazard posed by the stream itself, the Vermont Route 155 bridge at this location is also significantly undersized (54% of reference bankfull width) and increases the hazard posed to land upstream.
<i>Assets and Liabilities</i>	Land on the right bank is field.

M11-A: Mount Holly/East WallingfordCurrent Condition

Mill River segment M11-A is one of two mainstem reaches that run through the Village of East Wallingford. Due to the relative location of the village to the river, extensive channel straightening, armoring, and dredging have altered this channel, likely in response to past flood events.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Village B District • Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	Vermont Route 155 and commercial and residential development have significantly encroached on the channel. The bridge at the downstream end of the reach appears to be a debris/ice jam potential hazard - it already has held enough sediment behind the middle pier for a fully vegetated mid-channel bar to form. In addition a railroad bridge crossing which funnels both a road and the river underneath appears to be limiting sediment transport. The upstream aggradation the bridge is likely increasing an erosion issue on pasture land on the left bank of M11-B. Surprisingly, despite the high level of development, the draft FEH corridor affects only two single-family residences located just upstream of the Route 140E bridge (Figure 2). This is largely due to Vermont Route 155 acting as a new valley wall through this reach and protecting the development on its eastern flank. Berming to protect the residence on the right bank is already significant.
<i>Assets and Liabilities</i>	Continued development in the Village setting may be expected.



Figure 2: FEH Zone (red), berms (green) and structures at end of reaches M11-A and T2.01-A.

M10: East Wallingford

Current Condition

Mill River reach M10 flows through East Wallingford Village. This short reach has been highly managed in order to maintain its location and minimize flooding in the Village. RRD observed evidence of extensive channel straightening and armoring and a high incision ratio. Due to the significant investment in infrastructure within this reach the Mill River is likely to be maintained near its current configuration.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none">• Village B District• Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	Deteriorating bridge conditions on Village Street may provide an opportunity for redesigning access to the Village and or at least allowing better sediment and water transport under the bridge (which is currently holding sediment in its mid-pier and may create debris jam and flooding under the right conditions). Numerous houses exist within the FEH corridor (Figure 3).
<i>Assets and Liabilities</i>	Continued development pressure in the village may be expected.

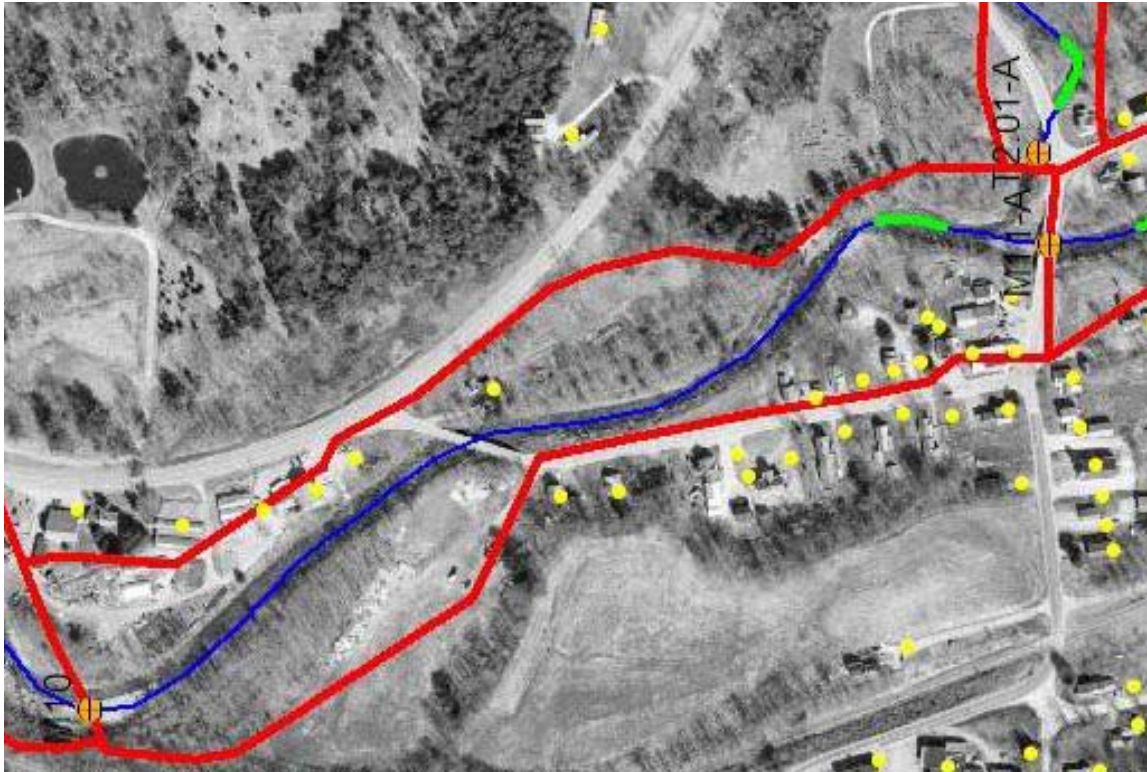


Figure 3: Structures (yellow) located in the FEH Corridor (red) in E. Wallingford Village

M09: East Wallingford

Current Condition

Although development pressure is not as significant as in the reach upstream, Mill River reach M09 has been impacted predominately by VT Route 103 which has changed the valley width from broad to narrow. In order to protect the roadway and a few structures located within the river corridor, extensive berming and channel armoring has occurred. Berming and straightening has increased the erosive forces in the channel leading to a high degree of incision (ratio of 1.8). Adjusting to this incision, the stream has undergone extreme channel widening. Extensive channel management (riprap, dredging, straightening) has prevented the channel from developing new floodplain and storing sediment.

FEH Opportunities and Challenges

Existing Zoning	<ul style="list-style-type: none">• Rural District• Flood Hazard Areas Zoning defined by FIRM Maps
Existing Structures	Despite a high level of floodplain encroachment only one structure (a residence) currently exists in the proposed FEH overlay zone.
Assets and Liabilities	None identified.

**M08: East Wallingford**Current Condition

Mill River reach M08 is a short reach in a semi-confined valley that has been further confined by Vermont Route 103. Despite a high degree of historic channel incision the stream retains access to floodplain during only the largest events. As a result of the incision the current sediment and floodwater storage capability of this reach has been significantly reduced.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none">• Rural District• Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	Two houses are located on the edge of the proposed FEH Zone on the right bank (Figure 4).
<i>Assets and Liabilities</i>	None identified.

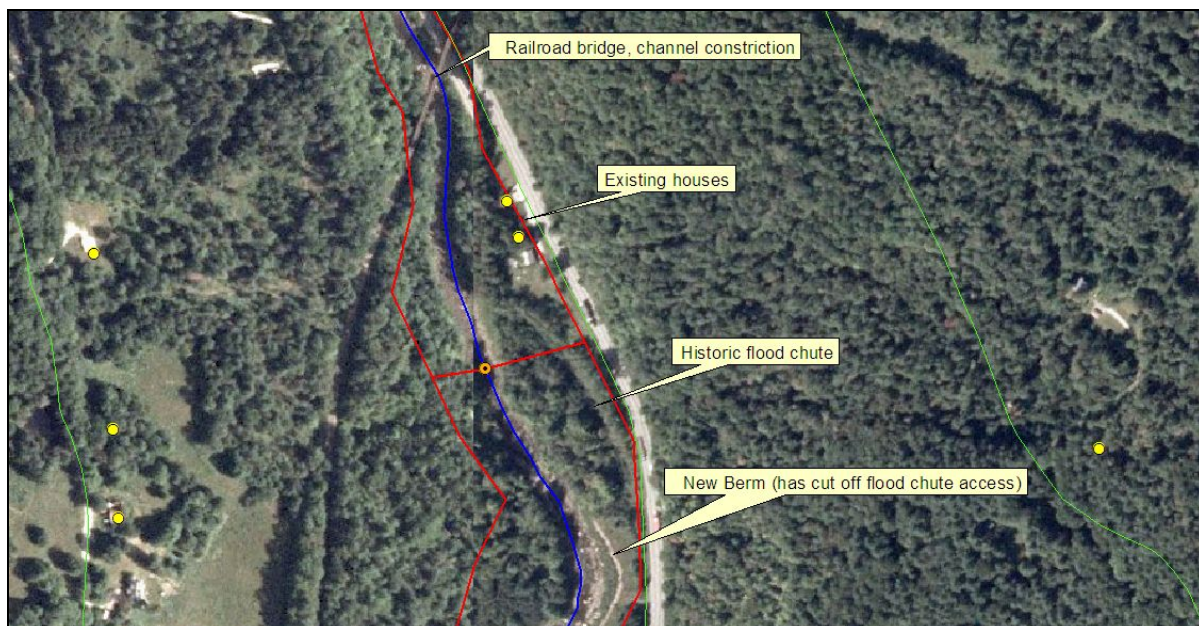


Figure 4: Structures located in the FEH zone in reach M08.

M07: East WallingfordCurrent Condition

Mill River reach M07 is a very short reach that appears to have been straightened up against the left valley wall in order to increase cultivatable land. Significant berming has occurred on the right bank in order to prevent flooding. Incision and channel widening have occurred.

*FEH Opportunities and Challenges*

<i>Existing Zoning</i>	<ul style="list-style-type: none">• Rural District• Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	Two houses are located on the edge of the proposed FEH Zone on the right bank, one of which is significantly protected by an existing berm (Figure 5).
<i>Assets and Liabilities</i>	None identified.



Figure 5: Structures in the draft FEH reach M07.

M06: East Wallingford/ShrewsburyCurrent Condition

Mill River reach M06 runs directly through Cuttingsville Village (Figure 6) with a great deal of human alteration, both historic and recent. Channel straightening, berming, dredging, armoring, and windrowing were all observed. Additionally much of the floodplain has been filled by development and roads increasing stormwater inputs into the system. It appears that the stream may have been straightened and relocated up against the left valley wall through much of the reach. A high degree of incision (1.8 ratio) was observed with major channel widening and planform adjustments currently occurring.

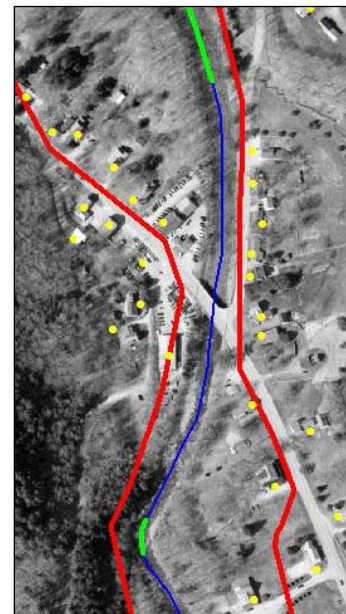


Figure 6: Structures (yellow) existing in the draft FEH overlay zone (red) through Cuttingsville Village (reach M06).

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Upstream portion is in the Wallingford Rural District • Wallingford Flood Hazard Areas Zoning defined by FIRM Maps <hr/> <ul style="list-style-type: none"> • Predominately in the Shrewsbury Cuttingsville District • Small portion in the Rural Residential (Min lot size 4 acres on north side – right bank) and Limited Residential (Min lot size 10 acres on south side – left bank)
<i>Existing Structures</i>	As with many typical Vermont village settings, the Village of Cuttingsville has significant amounts of existing residential and commercial development within the proposed FEH overlay zone.
<i>Assets and Liabilities</i>	Village growth may put more development pressure in this reach.

M05-B: ShrewsburyCurrent Condition

M05-B, as with many segments upstream, is heavily influenced by recent and historic channel management activities including berming, armoring, dredging, and windrowing. Floodplain encroachment from VT 103 and residences and commercial development along with significant channel straightening have led to an incised stream with less capacity to attenuate floodwaters and sediment. A berm at the upstream end of the reach has prevented access to a major flood chute. Active major widening is occurring in response to channel incision. The planform and widening adjustments are limited by the valley wall, armoring, and dredging.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	Rural Residential (Min lot size 4 acres)
<i>Existing Structures</i>	Six existing residential and commercial structures are located in the proposed FEH Zone.
<i>Assets and Liabilities</i>	None identified.

M05-A: ShrewsburyCurrent Condition

Mill River segment M05-A flows through a well forested corridor. Limited encroachment by the railroad track has impacted the right corridor. The channel has incised enough to abandon an old floodplain and begin to develop a juvenile floodplain. The degree of channel incision is low enough so that the stream remains able to store flood waters during the largest events. A large mass failure within this reach is a source of fine sediment and gravels to the downstream system. Several large flood chutes exist in the stream corridor indicating planform adjustment.



FEH Opportunities and Challenges

<i>Existing Zoning</i>	Rural Residential (Min lot size 4 acres on north side – right bank) Limited Residential (Min lot size 10 acres on south side – left bank)
<i>Existing Structures</i>	None
<i>Assets and Liabilities</i>	The land within the FEH corridor is predominately forested. A good portion of the lower reach is public land. Some land on the right bank is protected from development due to the railroad and the railroad r.o.w. The FIRM Map does not cover the area of land that is needed for the river to maintain long term stability (Figure 7).

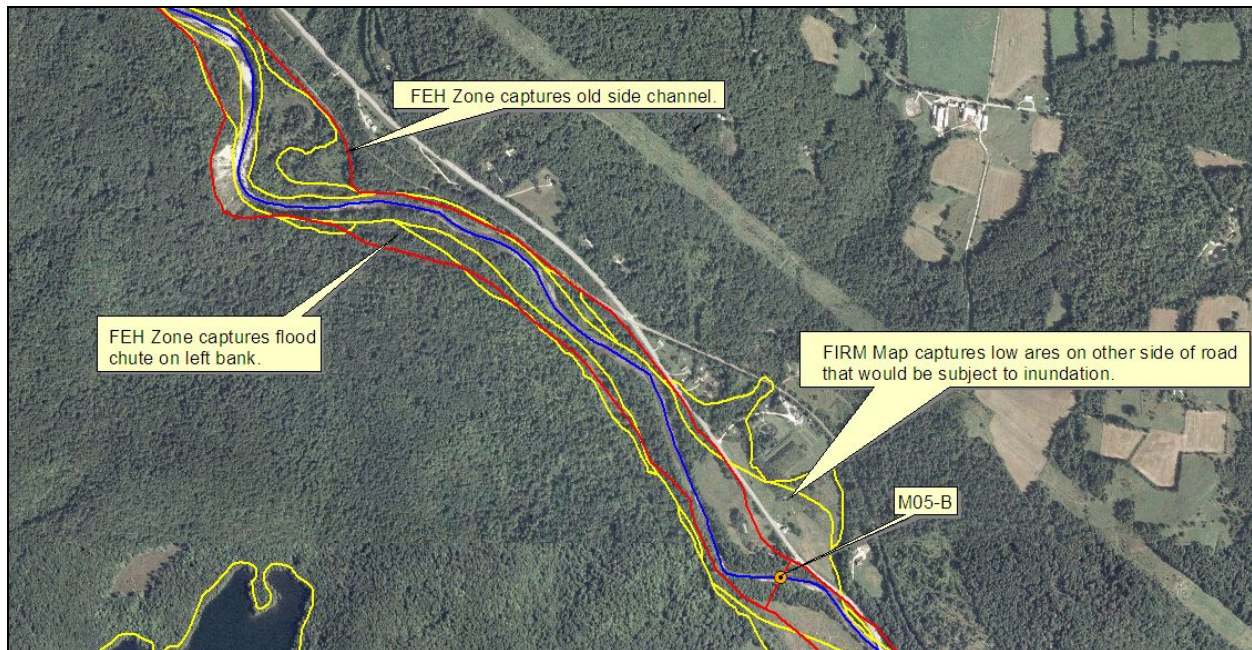


Figure 7: Variations in the FIRM boundaries and FEH zone on reach M05-A.

M04: Shrewsbury/Clarendon

Current Condition

Mill River reach M04 encompasses the Upper Clarendon Gorge. The bedrock gorge begins at a sharp southwestward bend in the river where a Long Trail suspension bridge hangs from the bedrock cliffs on each side.



FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Limited residential (10 acre lots size) in Shrewsbury • Conservation land with residential development on the fringes <hr style="border-top: 1px dashed black;"/> <ul style="list-style-type: none"> • Zoned Residential in Clarendon • In Clarendon Flood Hazard Zoning Permit required in FIRM area
<i>Existing Structures</i>	None.
<i>Assets and Liabilities</i>	Due to the highly stable nature of the bedrock gorge, the FEH zone for this reach is the existing bankfull width and does not affect the adjacent land which is currently forested. Almost all of the land in this reach is publicly owned.

M03-C: Clarendon

Current Condition

This segment is located between the Upper Clarendon Gorge (a bedrock controlled section) and the bedrock controlled segment at the former Kingsley Mill site. Channel incision observed here may be a result of the river working back through sediments that were stored when there was a mill dam, or due to a sediment imbalance upstream.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Zoned Conservation (some residential at outer perimeter of FEH) • Flood Hazard Zoning Permit required in FIRM area
<i>Existing Structures</i>	There are several residences encroaching on the river corridor on the left bank as part of development happening on Knipes Drive.
<i>Assets and Liabilities</i>	Most of the land is zoned for Conservation, however, development may still occur (Figure 8). Also The riparian buffer has suffered in this area due to development in the FEH zone.

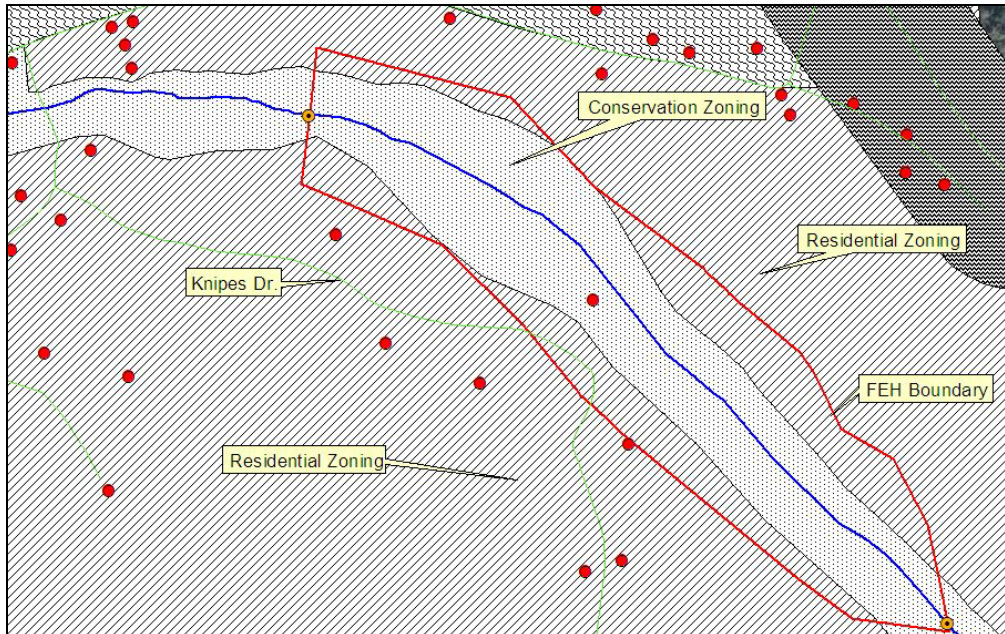


Figure 8: Areas where residential zoning and the FEH zone overlap in reach M03-C.

M03-B: Clarendon

Current Condition

Segment M03-B is a short bedrock controlled segment that includes the former Kingsley Mill dam site. Bedrock in the stream channel bottom and bedrock on most of the banks provide long-term stability to this reach.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Zoned Conservation (some residential at outer perimeter of FEH) • Flood Hazard Zoning Permit required in FIRM area
<i>Existing Structures</i>	Although some residential development has affected the riparian buffer, in general the bedrock has created a stable geomorphic condition in this segment. Adoption of an FEH overlay may only affect the Kingsly Mill House as it may exist within the bankfull width – which is the extent of the FEH Zone here.
<i>Assets and Liabilities</i>	Bedrock walls and steep banks will limit development in the river corridor.



M03-A: Clarendon

Current Condition

Mill River segment M03-A is also located between two bedrock grade controlled segments. Although this segment is slightly incised, it seems to be an area of sediment and floodwater attenuation, having large gravel bars, accessible floodplains and a forested buffer greater than 100 feet on both sides. As a result of the incision there is evidence of widening that has occurred in this segment. Minor planform and aggradation were observed as the stream rebuilds floodplain on both the left and right banks. This area will likely continue to be an important area in the lower Mill River watershed for sediment and floodwater attenuation.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Zoned Conservation (some residential at outer perimeter of FEH) • Flood Hazard Zoning Permit required in FIRM area
<i>Existing Structures</i>	None
<i>Assets and Liabilities</i>	Adoption of an FEH overlay zone would not affect this reach which is already land that is conserved by the VT Dept of Forest Parks and Recreation and the Vermont Housing and Conservation Board and therefore is not under significant risk of future development.

M02: Clarendon

Current Condition

Mill River reach M02 consists of the Lower Clarendon Gorge. The gorge is carved through bedrock which provides long-term stability to this reach.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Zoned Conservation • Flood Hazard Zoning Permit required in FIRM area
<i>Existing Structures</i>	None
<i>Assets and Liabilities</i>	Due to the highly stable nature of the bedrock gorge, the FEH zone for this reach is the existing bankfull width and does not affect the adjacent land which is currently forested. Also, most of land is publicly owned.

**M01-B: Clarendon**Current Condition

Mill River segment M01-B is a C-type channel by reference in a very broad valley. Significant channel management in the form of straightening, dredging, berming, and armoring has significantly altered the channel dimensions and entrenchment of this segment. The current incision ratio was observed to be 1.8 indicating that both berming and bed degradation have affected the nature of the channel. A landowner whose family has managed much of the surrounding land recounts the 1973 flood that washed out the railroad bridge. He noted that there was significant dredging of the stream channel after the 1973 flood between the railroad bridge and Route 7. He also noted that in the 1950's the area below the railroad bridge was dredged for gravel to help build Route 103.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Zoned Residential • Flood Hazard Zoning Permit required in FIRM area
<i>Existing Structures</i>	Railroad bridge is a channel constriction.
<i>Assets and Liabilities</i>	Short segment with a large portion in the Route 7 and railroad right-of-way's which will limit development potential.

M01-A: ClarendonCurrent Condition

M01-A is the lowest reach of the Mill River. This segment is located at a highly dynamic zone where floodwaters and sediment coming down from the relatively steep Green Mountain hillsides are released in the flat valley bottom of the Otter Creek. Scientists from RRD and VTANR observed a high degree of bank erosion and channel adjustment in this segment. The steambank material is composed of silts and clay near the confluence with the Otter Creek and the bank height increases significantly which is likely due to the influence of the Otter Creek.

FEH Opportunities and Challenges

<i>Existing Zoning</i>	<ul style="list-style-type: none"> • Zoned Residential • Flood Hazard Zoning Permit required in FIRM area
<i>Existing Structures</i>	None
<i>Assets and Liabilities</i>	Much of the land in this reach is under agreement with the CREP program.

T2.01-B: Mount HollyCurrent Condition

Tributary T2.01-B begins at the Bowlsville Road Bridge and ends downstream near the west entrance to Millbrook Lane. The upper portion of this segment is in fair geomorphic condition. It has undergone major historic incision, however, is actively working to redevelop floodplain. Active planform adjustment has led to the development of small gravel bars and a juvenile floodplain in some areas. Continued planform, widening, and aggradation adjustments are expected.



FEH Opportunities and Challenges

<i>Existing Zoning</i>	Flood Hazard Areas Zoning defined by FIRM Maps
<i>Existing Structures</i>	Adoption of an FEH overlay will affect numerous private landowners, six of which have homes located within or directly bordering the draft FEH corridor (Figure 9).
<i>Assets and Liabilities</i>	Stream is in fairly stable condition.



Figure 9: Houses crowd the FEH zone in reach T2.01-B.

T2.01-A: Mount Holly

Current Condition

Tributary segment T2.01-A has seen extensive historic channel straightening and armoring. There is also evidence of dredging and windrowing just above the Route 140-East Bridge. The right side of the floodplain has been filled almost entirely by Routes 140 and 103 which create the top of the right bank. On the left side of the channel the riparian buffer has been cleared down to a thin strip of vegetation along the top of the bank. Agricultural land use dominates the left corridor while commercial and residential land use dominates the right corridor

FEH Opportunities and Challenges

<i>Existing Zoning</i>	Flood Hazard Zoning Permit required in FIRM area
<i>Existing Structures</i>	With an extreme sensitivity rating, the two structures located within the FEH Zone of this reach are at risk (Figure 10).
<i>Assets and Liabilities</i>	Stream has been significantly altered. Much of the land is undeveloped on the left bank.

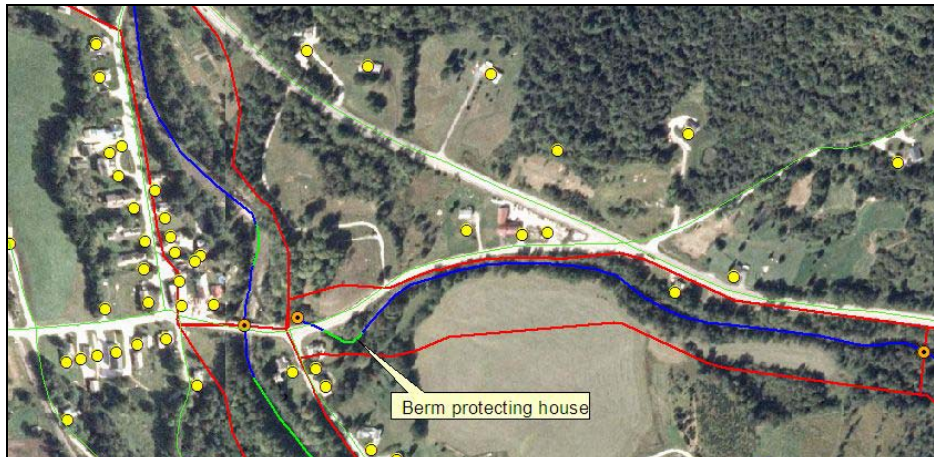


Figure 10: Encroachments and opportunities along reach T2.01-A in Mount Holly and E. Wallingford.

5.0 CONCLUSION AND RECOMMENDATIONS

Based on the results of this limited FEH Analysis the following broad conclusions and recommendations can be made:

Conclusions:

- The greatest concentration of structures lies in the village centers of East Wallingford and Cuttingsville. Here FEH zoning would affect the greatest number of landowners.
- Many reaches have little or no existing structures in the FEH corridor. Although land use restrictions would affect many landowners, proactively addressing the issue of development in the FEH corridor through proper zoning is important considering the ongoing losses that occur in Vermont due to fluvial erosion and the current and expected channel adjustment processes ongoing in many reaches. Designation of an FEH corridor in the reaches with little or no existing structures would be a proactive approach that may assist in long term channel stability.

Recommendations:

- The Towns of Clarendon, Shrewsbury, Wallingford, and Mount Holly should work with the VTANR and the Rutland Regional Planning Commission to consider the implementation of a FEH Overlay District into their Zoning Bylaws. FEH overlay districts would help reduce the risk of future property damage through the prevention of further development in the FEH corridor.
- Even if an overlay zoning district is not adopted, identification of an FEH corridor may deter some detrimental construction from occurring. Education about the FEH corridor and erosion hazard risks would be a valuable service for landowners and may lead to voluntary restrictions on development in the river corridor.



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